S. HRG. 101-1146

PROBLEMS AT NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

HEARING

BEFORE A

SUBCOMMITTEE OF THE

COMMITTEE ON APPROPRIATIONS

UNITED STATES SENATE

ONE HUNDRED FIRST CONGRESS

SECOND SESSION

SPECIAL HEARING

Printed for the use of the Committee on Appropriations

U.S. GOVERNMENT PRINTING OFFICE

36-778 ==

WASHINGTON : 1991

S181-29

For sale by the Superintendent of Documents, Congressional Sales Office
U.S. Government Printing Office, Washington, DC 20402

COMMITTEE ON APPROPRIATIONS

ROBERT C. BYRD, West Virginia, *Chairman*

DANIEL K. INOUYE, Hawaii
ERNEST F. HOLLINGS, South Carolina
J. BENNETT JOHNSTON, Louisiana
QUENTIN N. BURDICK, North Dakota
PATRICK J. LEAHY, Vermont
JIM SASSER, Tennessee
DENNIS DECONCINI, Arizona
DALE BUMPERS, Arkansas
FRANK R. LAUTENBERG, New Jersey
TOM HARKIN, Iowa
BARBARA A. MIKULSKI, Maryland
HARRY REID, Nevada
BROCK ADAMS, Washington
WYCHE FOWLER, JR., Georgia
J. ROBERT KERREY, Nebraska

MARK O. HATFIELD, Oregon
TED STEVENS, Alaska
JAMES A. McCLURE, Idaho
JAKE GARN, Utah
THAD COCHRAN, Mississippi
ROBERT W. KASTEN, JR., Wisconsin
ALFONSE M. D'AMATO, New York
WARREN RUDMAN, New Hampshire
ARLEN SPECTER, Pennsylvania
PETE V. DOMENICI, New Mexico
CHARLES E. GRASSLEY, Iowa
DON NICKLES, Oklahoma
PHIL GRAMM, Texas

JAMES H. ENGLISH, *Staff Director*
MARY S. DEWALD, *Chief Clerk*
J. KEITH KENNEDY, *Minority Staff Director*

SUBCOMMITTEE ON VA, HUD, AND INDEPENDENT AGENCIES

BARBARA A. MIKULSKI, Maryland, *Chairman*

PATRICK J. LEAHY, Vermont
J. BENNETT JOHNSTON, Louisiana
FRANK R. LAUTENBERG, New Jersey
WYCHE FOWLER, JR., Georgia
J. ROBERT KERREY, Nebraska

JAKE GARN, Utah
ALFONSE M. D'AMATO, New York
CHARLES E. GRASSLEY, Iowa
DON NICKLES, Oklahoma
PHIL GRAMM, Texas

KEVIN F. KELLY, *Clerk to Subcommittee*
CAROLYN E. APOSTOLOU
PAMELA T. DUVALL

Minority Staff
STEPHEN H. KOHASHI

CONTENTS

	Page
Statement of Adm. Richard H. Truly, Administrator	1
Opening remarks of Senator Mikulski	1
Opening remarks of Senator Garn	3
Opening remarks of Senator D'Amato	6
Introductory remarks of NASA Administrator	7
Current status of Hubble space telescope	7
Space Station Freedom resource requirements	8
Space station extra vehicular activity [EVA] requirements	9
Status of space shuttle hydrogen leaks	9
Complexity and risks inherent in NASA programs	10
Prepared statement of Adm. Richard H. Truly	12
NASA management	23
NASA response to *Challenger* accident	24
Agenda of advisory committee on the future of the U.S. space program	24
Patterns in cost overruns in NASA programs	25
Factors involved in cost overruns	26
NASA assessment of space station EVA	26
Purpose of space station preliminary design review	27
Experience concerning shuttle leaks	28
Post-*Challenger* shuttle software changes	28
Public relations versus policy concerns	29
Resource requirements versus mission content	30
Hubble space telescope cost estimates and testing	31
Critical support of NASA growing	32
Cutting-edge technology	32
One-of-a-kind versus multiple NASA programs	33
Current Hubble capability and future repair plans	34
Hubble testing	35
NASA practice regarding testing	36
Hubble specification test	36
Detecting Hubble's flaws	36
Testing the big picture	38
End-to-end testing	39
Possible contamination problems	39
Expected completion of General Allen's report	40
Wide field planetary camera	40
Statement of James M. Beggs	41
Additional committee questions	52

PROBLEMS AT NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

WEDNESDAY, JULY 18, 1990

U.S. SENATE,
SUBCOMMITTEE ON VETERANS AFFAIRS, HOUSING AND URBAN DEVELOPMENT, AND INDEPENDENT AGENCIES,
COMMITTEE ON APPROPRIATIONS,
Washington, DC.

The subcommittee met at 1:33 p.m., in room SH-216, Hart Senate Office Building, Hon. Barbara Mikulski (chairman) presiding.

Present: Senators Mikulski, Leahy, Garn, D'Amato, and Gramm.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

STATEMENT OF ADM. RICHARD H. TRULY, ADMINISTRATOR, NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

ACCOMPANIED BY:

DR. WILLIAM LENOIR, ASSOCIATE ADMINISTRATOR FOR SPACE FLIGHT, NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

LENNARD A. FISK, ASSOCIATE ADMINISTRATOR FOR SPACE SCIENCE AND APPLICATIONS, NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

JAMES M. BEGGS, CHAIRMAN, SPACEHAB

OPENING REMARKS OF SENATOR MIKULSKI

Senator MIKULSKI. We are waiting a few minutes for Senator Garn. I have already had a chance to talk with you this morning. What you are hearing is a Senator with a cold and I apologize for sounding so gravely. We are going to begin shortly.

From my vantage point I can see Senator Garn coming in the room, so we will begin the hearing.

The subcommittee will come to order.

This subcommittee is the Subcommittee on VA, HUD, and Independent Agencies. And one of our most vigorous agencies is NASA.

This afternoon the subcommittee meets to begin its inquiry of recent problems at NASA, and particularly in three programmatic areas: the Hubble telescope, the space shuttle and the space station.

As the committee prepares to mark up its 1991 appropriations, new questions have been raised as to whether NASA's 1991 budget is either affordable or achievable given most recent setbacks. Our hearing today is designed to help answer those questions.

As my colleagues know, I am a space Senator. My own record of support for NASA and other civilian space programs, for our Nation's space program is longstanding and clear and I hope outstanding. I believe in the values and ideals and goals for which NASA has stood and continues to stand.

In addition, the State I represent is very fortunate to have a strong historical link to the space program through the Goddard Space Flight Center and now, most recently, the Space Telescope Institute.

However, I am deeply troubled by the recent turn of events in NASA's program over the last month. It will be the job of the committee to take a look at whether these are isolated incidents or whether there is a systemic problem.

First, on the issue of the Hubble, the discovery of a serious flaw in Hubble's primary mirror has dealt a devastating blow to NASA. The mirrors were the one element throughout Hubble's troubled history that were considered near perfect. What is most disturbing about the discovery of this flaw is that it sums up the history of the spectacular space-based project: cost overruns, NASA and contractor mismanagement, and the frequent absence of quality control.

If Hubble were an isolated incident, that in itself would be serious enough. Unfortunately, the mistakes from which it seems to have suffered are not unique. So our principal focus today will be to find out why Hubble went wrong and why.

But we also need to take a look at other issues, the shuttle for example. In addition to problems with the hydrogen leaks in the space shuttle program which have delayed launches, there are other problems to be addressed.

I think NASA should be commended for discovering these leaks. And Admiral Truly, I think it is a testament to your commitment to safety for the space shuttle and for the astronauts who serve this country that you made sure that nothing left the ground where else there had not been that quality control check. I think you are to be commended rather than to be criticized to say safety first. So when the shuttle flies, it flies with a reasonable degree of certainty.

But at the same time there are these recurring delays in the shuttle flight rates. The shuttle was originally promised to be like a space bus, going 50 or 60 times a year servicing whatever space technology we have. Now it can only do 12 flights a year.

Then we come to the space station and now, again, there are more concerns that have been raised about it. We put $4 billion into the station. But now there are those critics who say it is overweight, underpowered, and has serious problems. As you know I support the space station. We cannot do human exploration without it. It has lofty goals for space research. But I think it faces a significant number of problems and we are going to talk about it.

Let me just wrap up by saying I think it is the goal of this subcommittee to have a space program that is affordable and is achievable. We need a reliable transportation system. We want to maintain and fund adequately NASA's core which is its excellent centers that are working. And we need to invest in basic scientific and aeronautical research.

We welcome Admiral Truly and his team. Later on we will be hearing from Mr. Beggs, who was the NASA Administrator during Hubble. Our questions today will be tough, but they are meant to help us work toward the same goal, the strategic framework for America's space program that is achievable and affordable, that builds on past successes without repeating past mistakes.

I now turn to my ranking minority, the astronaut Senator on this subcommittee, Senator Garn.

OPENING REMARKS OF SENATOR GARN

Senator GARN. Thank you, Madam Chair.

First of all, let me commend you for your initiative in convening this hearing with NASA to discuss the agency's response to recently identified problems in the Hubble space telescope and the last two planned shuttle launches and to review the current status of the space station program.

It has been extremely distressing to me that the media and some politicians have seized on some aspects of these concerns as raising doubts as to the competency of NASA and a potential rationale for further budget cuts in the agency's ongoing programs. That is why I feel it is so important that our subcommittee fully air these issues in our hearing to correct the perception that the discovery of technical problems somehow implies technical incompetence.

In my opinion, quite the reverse is true. So long as NASA pursues advancement in state-of-the-art, cutting—edge technology areas, technical problems and challenges are necessary to achieve those goals. The real test of agency competence is how these issues are addressed and resolved. I look forward to Admiral Truly's presentation in this regard.

I do want to emphasize that. I see the press out there as a bunch of piranha and some of my colleagues the same, fortunately not on this subcommittee and not with this chairperson, but others who seem to enjoy kicking someone when they are down. And yet I look at the incompetencies in Government and other agencies that are dealing with everyday things that should not have mistakes because we do them over and over again.

When you realize that when I was a senior in college nothing had flown in space, absolutely nothing, not *Sputnik*. And if anybody had told me at that time that I would have the opportunity to orbit the Earth 109 times in a reusable spacecraft, obviously, I would have laughed about that because *Sputnik* and our own first 2.5-pound satellite had not flown.

So when you consider in such a relatively brief period of time, from the late 1950's, not having the ability to fly anything in space—and we experienced this with the *Challenger* accident. Nobody talked about the fact that 52 manned missions were successfully completed in space without a fatal accident. They concentrated on the *Challenger* accident. And no one felt worse about that than I did.

Mike Smith, the pilot of that flight was my trainer, and I spent 4 months with that man. I knew his wife and children. And I knew every member of that crew. But also every member of that crew and my crew and Dick Truly's crews were volunteers. There were

not draftees; there never has been on the space shuttle or in any space mission. Every one of us were trained. We knew exactly what we were doing and we wanted to do it. You cannot guarantee safety in space, no matter how hard we work, no matter how many times we shut down because we have got a leak in the 17-inch line.

Anybody who has flown knows that this is the most technologically complex machine that man has ever built. And there are going to be problems. And as you rightfully did, Madam Chair, you pointed out that NASA has never, ever sent a mission that they did not think was as safe as possible, including *Challenger*. Rather than being condemned for shutting down the space flights until they find those leaks, they should be commended for doing exactly what the Rogers Commission report and many of us in Congress said they should do: minimize those risks.

I do not understand what is going on. I do not understand the lumping together of all of these events because I know that if Hubble were sending back beautiful pictures nobody would be questioning NASA management or do we need an outside panel to come in and investigate. We did that exhaustively with the Rogers Commission report. Space centers were reorganized. Management was changed. All sorts of changes have gone on. We created a special safety division, created America's No. 1 astronaut as far as time in space—six flights—John Young, to head up that group. All of those things have been done.

Now some people want to reinvent the wheel. You can shake up NASA management every day of the week. You can turn it upside down. You can get rid of Dick Truly and Fisk and Lenoir and everybody else. You can change the Congress. And that would not have prevented the technical tragedy that has taken place because of the lack of some proper tests 10 years ago.

I am sorry to take so much time, but it disturbs me. As one who has been inside NASA. It still has the most technically competent, capable people of any Government agency, and the most dedicated astronauts, the cream of the crop of America's scientists, pilots, and administrators. There is not another agency that compares.

But we are going to kick them when they are down and we are going to take isolated events and bring them together. The problems of Hoot Gibson and David Walker of being grounded have nothing to do with the internal management of NASA or problems. They are being disciplined for questionable activities in piloting aircraft and has nothing to do with the space program.

Yet, the press has to say, oh, we've got Hubble, we've got the shuttle, and we've got these astronauts and all these problems, like they are just groping and looking, finding every little tidbit to make the agency look bad.

Well, this Senator resents that. I would like to take some of those people with me. I would like to have them spend some time down there and see how these people work, all throughout NASA, the cast of thousands that make a mission possible, not just for the astronauts. Then I would like to take some of the gutless wonders out there on a space shuttle trip, if they had the nerve to go. I would probably need some big diapers, however, to take care of their problems.

In any event——

Senator MIKULSKI. This is not a health hearing.

Senator GARN. In any event, I want to compliment the chair on holding these hearings and her attitude. She is a space Senator; she is a friend of NASA. And her conduct of these hearings compared to some of the others that I have seen is in the nature of trying to find out what problems there are and seeing if we can be of help. I appreciate that very much.

On the issue of NASA's pending budget request, I must be less than optimistic that we will accomplish as much in clarifying existing confusion over our future course. Unlike activities of NASA, no one has ever had any expectation that the congressional budget process could be conducted with any order and competence.

Unfortunately, just when some thought that it could not get any worse, it has. Yesterday, the full Senate Appropriations Committee voted its 302(b) budget allocation to its subcommittees. This subcommittee received $2 billion in budget authority and $630 million outlays less than the level approved by the House in its version of our appropriations bill. Unless this allocation is revised, NASA's funding will have to be cut from the already constrained House-approved level.

It is clear that the implications of such reductions will be devastating to ongoing programs such as the space station and the shuttle and may force further program cancellations such as AXAF and CRAF/Cassini, even high-priority new starts such as Global Climate Change Program, known as Mission to Planet Earth, which is highly important to this subcommittee.

When I consider how disruptive and costly these actions will be to NASA's programs, that such funding turmoil in past years has been for the three programs that we are discussing today, I get exasperated by those who suggest that somehow NASA management or organization is to blame.

Those who call for new task forces and investigations should perhaps look a little more closely at home to identify some needed reforms. I would remind everybody who is listening that NASA's entire budget is only a little over 1 percent of the entire national budget.

Back in John Kennedy's days as President, NASA was growing to over 4 percent of our national budget. We have not properly funded NASA over the years considering the technological spinoffs and the benefits that come back from space research and development.

So I hope we can get back on track and recognize that, yes, NASA does have some problems. And, yes, NASA will always have some problems. I do not care who the Administrator is. I do not care who the President of the United States is. I do not care who is down there. When you are dealing with what I would call beyond cutting-edge technology, of doing things that men and women have never done before, you are going to have to expect some errors, things that do not work the first time or the second or the third. That has happened in the development of aviation. It happens in the development of all high tech things. But particularly in this area it is going to happen.

Are we going to have a review commission, are we going to call everybody to task every time it happens? If we do we might as well

close down the space program and say we are not going to that anymore. We are not going to accept the challenges. We are not going to be the leading nation in technological advancement in our world, in our-technological base.

We have got to recognize that risks are involved, that mistakes will be made. And, as I said in the beginning of my remarks, the question is how NASA and their scientists respond to these problems. How they correct them. I will guarantee you that we will get our money's worth out of Hubble.

Nobody is more disappointed than I am. I just cannot tell you from a public perception standpoint to have beautiful pictures coming back from Hubble, how that would help the chair and me in getting an adequate budget rather than having these kinds of hearings. So I am disappointed. So is everybody at NASA. But the question is how do we respond to those technical problems that will occur. How do we fix them?

And I will guarantee you that we will get our money's worth out of Hubble. It will be fixed. And we will get the science out of Hubble, unfortunately delayed. But nevertheless we will get it. And I would also remind everybody without even the fix, we will get 55 or 60 percent in ultraviolet and other areas that we expected to get. It is still a good telescope, not what we anticipated, but it will be.

I thank the chair for her indulgence. My opening statement ended up much longer than it was intended. But I do appreciate you allowing me to say it all.

Senator MIKULSKI. Well, Senator, you are the only one on this subcommittee who has ever been into space so we feel that your expertise and unique insight is most welcome.

Senator D'Amato, do you have an opening statement?

OPENING REMARKS OF SENATOR D'AMATO

Senator D'AMATO. I have a brief statement, Madam Chair. First of all, let me commend you for calling the hearing.

As Senator Garn has indicated I think we have witnessed something of a feeding frenzy in recent weeks as it relates to the media and to NASA. Now, obviously, the Hubble mistake is a major gotcha, but it is one that can be dealt with. It is one that can be corrected. And it is one where we certainly have the opportunity to learn from our mistakes.

Now, there are several questions with respect to Hubble that need answers. One, was the basic design of the mirrors wrong? Two, if the design was correct, was it a manufacturing error? Three, whose responsibility was it to exercise oversight of the design and manufacturing process? And, four, why did not the quality control process catch the mistake?

While it is too late to prevent the mistake that caused the error in Hubble, it is not too late to make certain that such a world-class mistake is not repeated. I think that is what we have to focus our attention on. And I believe that is what the chair is concerned about.

I look forward to working in that area in a cooperative way to see to it that we move forward, that we learn from those experiences.

In addition, I have several questions regarding NASA's assessment of the severity of Hubble's problems and the time needed to correct them.

Again, I want to commend the chair for her thoughtfulness and for her perspicacity in pursuing this and in the manner in which she has done so.

Senator MIKULSKI. Thank you very much.

Admiral Truly, the forum is now yours. We welcome your testimony on the Hubble and anything else you would like to share with us. If you would like to introduce your team accompanying you, we will be happy to proceed.

INTRODUCTORY REMARKS OF NASA ADMINISTRATOR

Admiral TRULY. Madam Chairman, thank you for the opportunity to testify before you today.

I will introduce those accompanying me. First, the Associate Administrator for Space Science and Applications, Dr. Len Fisk and Associate Administrator for Space Flight, Dr. Bill Lenoir.

This is not the type of hearing that NASA wants to come to. The reason is that we pride ourselves on mission success and safety. We are working hard to reestablish the credibility we have lost after the last couple of weeks of publicity.

But I am pleased to be here and talk to the committee today because you have asked me to come and talk about facts, about three issues: the Hubble space telescope, the space shuttle situation, and some issues on Space Station Freedom. I am always delighted to come to this committee and talk about facts.

CURRENT STATUS OF HUBBLE SPACE TELESCOPE

First, let me briefly tell you about the situation with the Hubble space telescope. Let me first start by saying that the failure of the telescope to properly and precisely focus is unacceptable to the NASA and the NASA contractor team. We take full accountability for the anomaly. In hindsight it appears that a simple error was made. It does appear with the data that we have now that it was in the manufacture of the mirror, although as I described, we have a team looking into that.

With hindsight, undoubtedly, we will find that the error was avoidable. And with hindsight we will find that there were some tests that were not done or not done properly that would have caught it.

The error is something called spherical aberration. That is a fancy word for saying that this large mirror of over 94 inches in diameter does not precisely focus its light beam at precisely the same focal point. In other words, the light bouncing off the edge of the mirror does not come to precisely the same point as the light coming from the center of the mirror.

That dimension that we are talking about is about one-half a wavelength of light at a certain frequency. And just to give you an

idea that is less than one-fiftieth of the diameter of a human hair. This is a very, very precise business.

In order to look into this matter we have appointed a review board, headed up by Gen. Lew Allen, who is the director of the Jet Propulsion Laboratory. I have asked Lew to answer three questions. First, how did this problem occur? When did it occur? And why did the program fail to discover it before launch?

The good news in this is that because this error is so symmetrical and simple, it is easily fixable. So we have another team that is working on the science planning to do two things. First, to use the capabilities of the telescope between now and the time we can get back to it, to use those capabilities to get good science in the interim. And second, to devise a simple fix and when we can get back to it, we will correct it so that Hubble, for the remainder of its 15 years of operating life, will be operating per the specification.

I can personally assure you that NASA is going to do everything that is possible to correct the deficiency as quickly as we can. We have already made, in our science management programs over the years since Hubble, changes in our quality procedures and our testing policies that would not allow this error, we believe, to occur today.

Finally, in summary on Hubble, let me tell you that the high technology components of the program, the fine guidance sensors, the faint object cameras, the attitude control are working well. It is this simple but unacceptable problem that is isolated in the mirror that is the issue on the table.

SPACE STATION FREEDOM RESOURCE REQUIREMENTS

Second, I would like to give you an update on some issues that have been in the press and that this subcommittee has dealt with on Space Station Freedom. They deal in the space station program with resource requirements. In other words, the delta between the power required, the resource allocations, the EVA—extra vehicular activity time—required to do maintenance compared to the requirements.

Let me start by reminding you that 1990 is the year of the preliminary design review of Space Station Freedom. This is a series of reviews we have been conducting during the year. A preliminary design review is the time in a big program where you look at the program early, precisely to find disconnects, when the design is at about a 10-percent maturity toward the final design. You expect to find problems. That is why you do the review. The subsystem design reviews are on schedule and being conducted. We are shooting for an integrated system design review in December.

The situation on the resources, particularly in the weight and power as we have briefed your staff and as we have briefed the public, is that we have unacceptably high levels to us at this point in the program comparing the preliminary design weights as they are coming in from the subsystem. Power required is an example; they are higher than they need to be. That is the purpose of the review. And by the end of the time that we deal with these problems, we will have them in hand.

Let me give you a personal observation, though, from my experience in the space program. This is precisely what happened in Apollo, precisely what happened in Skylab, precisely what happened in space shuttle. When you go through a preliminary design review, literally, you have a lot of work to do and the subsystem designers are at a very immature—not immature—but about a 10-percent design level. That is why you do it. But we do have problems. We are dealing with those problems. And it is my policy and our policy to be totally open with you and the public as we do that.

SPACE STATION EXTRA VEHICULAR ACTIVITY [EVA] REQUIREMENTS

A specific issue that has gotten a lot of press in the space station this year is extra vehicular activity and whether or not we have too much of it. And in fact, we do. Because we did, we formed a team earlier in the year that is headed up by two people down in Houston, Bill Fisher and Charlie Price. It has become known as the Fisher-Price team. They have almost come to the end of their review. I have not heard their story. They have done a good job, as has the solutions team that we have recently appointed to help find solutions to the problems that they raise.

In summary, they have concluded that the requirements for EVA's are higher than we can stand. The Fisher-Price team has made about 100 recommendations, some simple, some having to do with equipment or handrails or different things, some procedural that will help to reduce this EVA requirement. And the solutions team has done the same.

As I said, I have not heard the results of this study. It should be finished and getting to you next week, I think. But it is my understanding that the issue has settled itself quite well for the out-year requirements, the steady state maintenance of the station, assuming that we agree with and apply the recommendations that have been made. But there is still a significant issue about EVA requirements that build up during the assembly of the station. That is something that we will have to look at very carefully and vigorously, through the remainder of this year since they have now brought that to us.

The final thing I would like to say about station is simply that I think it is terribly important to keep the momentum that we have going alive. For the last year we have gotten station management well in hand. I believe we are bringing the program under configuration management in a good way. We are going to lose this momentum if we cannot get the support of the Congress in our request for the fiscal year 1991 budget. Funding reductions of the magnitude we have seen, even coming out of the House, not even considering the problems that your subcommittee faces, will impact our progress and the stability in the program. It is time to let the engineers go build the station, I believe.

STATUS OF SPACE SHUTTLE HYDROGEN LEAKS

The third issue that I would like to speak about briefly is the space shuttle and the two hydrogen leaks that we have encountered on the last two attempts to fly with *Columbia* and with *Atlantis*. In the case of the space shuttle and this issue, NASA risk

management and risk assessment has worked as advertised. Two hydrogen leaks that for a while we thought might be generic and indicate a problem that we had not known, turned out to be totally isolated, different leaks. We have isolated one of them in a laboratory in California. And we have isolated the other one, the *Atlantis*, which is still on the launch pad down at Cape Kennedy.

The coincidence of two separate hydrogen leaks and the discovery of this Hubble mistake that happened 11 or 12 years ago, to occur in 2 weeks is incredible to me. I do not know what the probability of that is, but it has come together to give us a desperate situation with you because of the appearance that it is a single problem and it has to do with the way NASA is being managed and run. My personal opinion is that nothing could be farther from the truth.

We are going to run another tanking test on *Atlantis* in just a few days, I think the 25th or something like that. The problem may be fixable right out on the launch pad. The problem has been isolated to a flange where the 17-inch disconnect valve bolts to the external tank. It may be as simple as checking torques, retorquing the attached bolts, making sure that it is safe, verifying that in the tanking test. If that is the case, we could be flying that mission in the first half of next month, of August. If that is not the case, and in this business, luck does not count for much. You just have to go and see if it works or not. If that does not work, we will roll that vehicle back into the VAB and change it out there and fix the leak in there. But it is straightforward. We know what we have to do.

We have a Ulysses planetary mission on October 5. We are confident we will make that. And we will fly one flight. If we are double lucky, as I said, could possibly even get off two flights before that mission. But we are not going to push the system hard. We are going to run these flights just the way that we have run the ones up to now.

And, frankly, I commend the NASA and contractor teams that have been working on the shuttle leak problems since then.

COMPLEXITY AND RISKS INHERENT IN NASA PROGRAMS

In summary, let me say that based on what I have read and heard and the conversations I have been in in the last 2 weeks, it is clear that these coincidences have challenged our credibility in a way that I want to—and I am glad to be able to lay this out in a factual manner. This agency reaches far, farther maybe than any other agency in the Government. We run exciting, productive, but very, very challenging programs. I would hate for this perception to drive us away from the substance of what we are doing.

We have a problem with Hubble that is on our ticket. It did happen a number of years ago. And we are going to get to the bottom of it, fix it and bring it back to shape.

But I think that NASA is more than capable of flying and initiating bold new missions. And the men and women of our agency and our contractor team across America are committed to giving this Congress and the American public the best possible civil space program for each dollar that is invested.

When you run complex programs that are run by human beings, failures and anomalies are going to happen. Space flight is a risky business. This country does not print enough money to take all the risk out of it. But it is worth doing. It is worth doing by a good agency and I think that we have one.

PREPARED STATEMENT

Let me also close by saying that I am particularly pleased in the last few days that I have gotten—I and the NASA team—have gotten such super support from the President and the Vice President. In all of this they are quite attuned to what we are doing and what the publicity has been. They have stuck by me all the way.

Thank you, Madam Chair.

[The statement follows:]

STATEMENT OF RICHARD H. TRULY

Madam Chair and Distinguished Members of the Subcommittee:

I welcome this opportunity to appear before you today to discuss the status of our investigation into the Hubble Space Telescope, our progress in identifying the sources of the liquid hydrogen leaks which have interrupted flight of the Space Shuttle, and the disposition of development of Space Station Freedom as we enter the Preliminary Design Review (PDR) process.

I would like to assure you that the men and women of NASA are working around the clock to identify the cause of, and to expeditiously correct, the anomaly we have recently identified in the Hubble Space Telescope and to safely and quickly return the Space Shuttle to flight. It is important to note that the recent experiences with the Hubble Space Telescope and the hiatus in Shuttle flight are distinctly different phenomena. Clearly, the spherical aberration discovered in Hubble represents a fundamental failure in NASA's prelaunch testing regime which is unacceptable, and for which NASA is wholly accountable; we are determined to restore Hubble's full capabilities at the earliest opportunity. On the other hand, our pre-launch identification of hydrogen leaks in Columbia and Atlantis represents the fully successful operation of NASA's post-Challenger safety procedures. Our civil servants and contractors have worked doggedly over the past few weeks to find the sources of these leaks, and we have been pleased to determine that the leaks are independent of one another, and, therefore, do not represent a generic problem in the orbiter system. Once the leaks are remedied, we expect to be in a position to resume safe Shuttle flight in the next several weeks.

I recognize that the standards placed upon NASA by the Congress and the American public are exceedingly high -- standards which NASA fully embraces. As a result, it is our view that any anomaly is unacceptable. We are committed to continue to deliver a civil space program which merits the pride of the nation, pushes the edges of technology, fosters economic competitiveness, and inspires our youth. We at NASA pledge our most diligent efforts to overcome the temporary setbacks in the Hubble Space Telescope and flight of the Shuttle, and will keep you and the Congress fully informed as we make progress toward that end. I will address the Hubble Space Telescope, the Space Shuttle, and Space Station Freedom, respectively, in the balance of this statement.

HUBBLE SPACE TELESCOPE

I would like to begin by outlining NASA's preliminary assessment of tests conducted on the Hubble Space Telescope (HST) over the weekend of June 23-24. Those tests suggested that HST is experiencing what we believe is spherical aberration, or an inability to focus light into a single, precise point. I want to stress that our understanding of this anomoly is incomplete and it remains under study; however, NASA feels it is important to maintain our policy of openness with the public and the Congress. In this regard, we are prepared to provide any briefings which you may deem

appropriate to keep you and the other members of Congress fully informed of this situation as it unfolds.

First, this spherical aberration is significant because it prevents Hubble from fulfilling one of its primary requirements, namely, that "70 percent of the total energy of a stellar image must be contained within a radius of 0.10 seconds of arc." Hubble is currently able to focus only 15 percent of an image's energy into that same area.

However, this aberration will not prevent Hubble from answering the fundamental questions about the universe it was built to investigate. New, exciting, and unique science will be conducted using Hubble in the near-term and over its entire 15-year lifespan, beginning almost immediately. Hubble will not be able to conduct certain scientific activities in the near-term, but it will be able to substitute significant science in a number of equally important areas. And over the next few years, Hubble's capabilities will be fully restored, allowing us to recapture the science that will be deferred in the interim.

It is important to remember that NASA was established to do challeging missions; missions that require men and machines that push the envelope of technology to, and sometimes beyond, its limits. The true test of NASA's abilities should be, and must be, how we react when confronted with adversity; how quickly and effeciently we overcome this problem. I am confident that we can, and will, overcome this.

Clearly, the first step has to be finding out the cause of this aberration. To accomplish this goal, we have established the Hubble Space Telescope Investigation Board to investigate the cause of this anomaly. This Board will be a working group charged to review, analyze, and evaluate the facts and circumstances regarding the manufacture, development and testing of Hubble's Optical Telescope Assembly. This Board is chaired by Dr. Lew Allen, the Director of the Jet Proplusion Laboratory, and is composed of world-renowed experts in optical systems and spacecraft quality control. Other members of the Board have been formally announced. They are:

Charles P. Spoelhof
(Retired) Vice President, Eastman Kodak Co.

George A. Rodney
NASA's Associate Administrator for Safety and Mission Quality

John D. Mangus
Head, Optics Branch, Space Technology Division
NASA's Goddard Space Flight Center

Prof. R. (Bob) Shannon
Director, Optical Sciences Center
University of Arizona, Tuscon

Dr. Roger Angel
Professor of Astronomy, Steward Observatory
University of Arizona, Tuscon

The Board held its first preliminary meeting in Washington, DC, on July 5-6. A copy of the Board's public statement following its first session is appended to this testimony.

The second step is to continue the process of characterizing this problem and to understand its impacts on the scientific goals of Hubble. Our goal will be to maximize the scientific return of Hubble in the near-term, as well as over its 15-year lifespan. On June 28, the Hubble Science Working Group issued a white paper which summarizes their preliminary assessment of the impact on the science program, a copy of which is also appended to this statement.

In the next few months, NASA will be working with the Space Telescope Science Institute (STScI) and the Science Working Group to reassess the scientific program for Hubble. Our initial assessment is that approximately 50 percent of the observations originally scheduled for HST are still viable. Part of the peer review panel that selected HST's first-year observations will be reconvened to reevaluate the proposals in light of Hubble's current strengths. It is important to remember that since there were ten times as many observations approved originally as could be scheduled during the first year, there is little doubt that HST will continue to be oversubscribed.

The third step of this process will be to develop and implement a long-term solution to the aberration. Our preliminary assessment is that the inclusion of a relatively small corrective mirror or lens in the front of the second generation instruments should eliminate the scientific impact of this aberration. It appears that this solution should be very staightforward and should not result in a significant cost or schedule impact in the devlopment of the new instruments. NASA will also explore accelerating the delivery of the new instruments, especially the second Wide Field/Planetary Camera, to further minimize the scientific impact.

What we are talking about here is not "losing science" as has been reported in the press; but rather, altering the mix across areas of science for the next few years. During this interim period, we will be deferring some significant science, primarily in visible light imaging, while substituting equally significent science. The bottom line is that visible light imaging will occupy a smaller portion of on-target observation time while ultraviolet observations, spectroscopy and astrometry will occupy a larger portion during the first few years. We fully expect that after the second generation instruments have been delivered on orbit, that all the science that is deferred will be successfully completed. And when examined over its full 15-year operational lifetime, the relative distribution of observation time across the science program will even out.

In fact, there appears to be the potential for acquiring additional visible and ultraviolet imaging science. We have formed a "tiger team" to review the potential benefits of various image processing or reconstruction techniques. It is

thought that such techniques could provide up to three times more resolution than the current performance and thereby make some of the imaging science viable. We should have some more definitive answers on this by mid-August.

In conclusion, I would like to emphasize three points. First, we are committed to determine how and when the problems in the Optical Telescope Assembly occurred which led to the observed spherical aberration, and how this aberration could go undetected prior to launch. Second, we are committed to strive forward in understanding this problem relative to its impact on the scientific goals of the program and subsequently maximize the scientific return of this facility both in the short term and the long term. Finally, we are committed to develop and implement a long-term solution to the aberration to assure that the full potential of the Hubble Space Telescope is realized. I believe that we will witness discoveries by the scientific community that will be characterized as world class. As Dr. John N. Bahcall, President, American Astronomical Society and Member of the HST Science Working Group, has so aptly stated, "When we read the history books of this decade, we will not notice the prescription for the Hubble mirror was slightly askew. But we will notice that we opened major new chapters in the understanding of the universe. It will be an intellectual revolution."

SPACE SHUTTLE

I am pleased to report that excellent progress has been made toward isolating the source of the liquid hydrogen (LH2) fuel leakage observed on both the STS-35 (Columbia) and STS-38 (Atlantis) vehicles.

The orbiter side of the LH2 umbilical from Columbia was shipped to Rockwell International, Downey, California, on June 30 and was mated to its external tank umbilical in a special test fixture. Successive testing has led us to conclude that the leak is in the area around seals associated with the shafts in the orbiter half of the umbilical which operate as part of the flapper valve closure. We are presently conducting further reviews to determine whether additional testing can be performed to provide additional data. While our conclusions are tentative, it is likely that having replaced the quick disconnect on Columbia will have solved the problem. Naturally, additional testing of the replacement system will be performed.

A second on-pad tanking test has been performed on Atlantis at the Kennedy Space Center. Leak detectors at the launch pad were reverified to be properly calibrated, and additional instrumentation was installed around the umbilicals. Bags were placed around all the critical suspect joints, and detectors were placed inside the bags to obtain precise measurements. Our review of data generated by this second on-pad tanking test has led us to conclude that the leak source is in the area of a flange which connects the quick disconnect to the external tank. We are presently studying whether additional tests may be productive before we remove test hardware from the umbilical. Our alternatives are still under review, but one solution might be to tighten the bolts securing the flange. We expect to decide on a

final adjustment to the umbilical joint and perform another tanking test on Atlantis around July 25.

We are currently evaluating our schedule options for candidate missions which can be launched before Ulysses. If the adjustment to the umbilical joint on Atlantis and the tanking test are successful, we could launch Atlantis as early as mid-August, with the potential of launching Columbia in mid-September. We remain confident of our ability to meet the fixed planetary window dictated by the Ulysses spacecraft.

I commend the NASA/industry team which has analyzed these problems, and which continues hard at work on this issue. Although we have some further work to do on understanding these leaks and determining corrective actions, the quick and decisive action of the team has been exemplary.

SPACE STATION FREEDOM

Turning to the Space Station Freedom program, I am pleased to report that we are progressing on schedule, and are now well into the Preliminary Design Review (PDR) process. We are conducting the work package PDRs on schedule, and will complete the remaining ones required to support the program-level integrated system PDR this December as planned. We are well on our way toward the scheduled First Element Launch (FEL) in March of 1995.

As we told you last year, "1990 is the year of the PDR." PDR is essentially an early check of preliminary designs at a point when the designs are approximately 10% complete. Its purpose is to ensure that the preliminary designs meet program requirements before activity moves into more detailed designs, and to surface any discrepancies between the emerging preliminary design and program requirements. In doing so, PDR provides an early look into potential problems at a point when there is ample time to resolve issues and refocus project efforts, as necessary.

Although the PDR process has already identified some discrepancies, we have not encountered any show-stoppers or obstacles that would require major programmatic, design or schedule changes.

With this brief introduction, I would like to provide you with an update on the status of two areas which have received attention recently. The first is the status of the requirements for extra-vehicular activity (EVA) for external maintenance for the Space Station, and the second is the status of availability of Station resources, such as power and weight.

With regard to the EVA/external maintenance situation, I can assure you that a significant effort is underway to bring this aspect of the program into acceptable levels. The Fisher-Price team that we set up last January is completing its function to determine EVA crew time required by current Station designs; to develop possible trade-offs between EVA time, robotics time, increased hardware reliability, and movement of Orbital Replacement Units (ORUs) inside pressurized areas; and, in general, to look at the entire requirement for external maintenance.

As you are well aware, the Fisher-Price team released their initial assessment in March. It provided results which indicated an unacceptable level of EVA maintenance time. Since that time, the Fisher-Price team has continued its analyses and provided a list of approximately 100 recommendations as to how EVA maintenance can be reduced. Many of these recommendations have already been incorporated by program management while others are being evaluated. The Fisher-Price team is currently preparing to release a more complete assessment next week.

To complement the Fisher-Price team study, we formed a "Solutions Team" to assess the early recommendations from the Fisher-Price analyses. Since much of the external maintenance data used by Fisher-Price was preliminary and had not yet been through the PDR process, the Solutions Team was also directed to consider improvements that could be made in the data base. The Solutions Team has provided some encouraging results, which will also be released when the Fisher-Price results are released next week.

Although I have not yet been personally briefed on any of these findings, I understand that the estimated EVA requirements for the current system design are still unacceptably high, but that each team is making recommendations that would greatly reduce EVA requirements to an acceptable value. These study efforts will establish a baseline, and our focus on EVA requirements will continue after formal release of the findings and recommendations of the studies. We will continue to evaluate options to reduce external maintenance requirements throughout the PDR process until we have in place a plan which reduces EVA maintenance requirements to an acceptable and safe level.

Through the PDR process, it has become apparent that the subsystem and work package initial designs currently demand unacceptable levels of Station resources. We are now assessing options for reducing resource demands to bring them within the levels that have been allocated in the Program Definition and Requirements Document (PDRD). This activity is focusing primarily on weight, power and data management system resources, and is producing options which are being brought to program management incrementally for program-wide assessment and disposition.

I believe that it is important to point out that, historically, in large and complex NASA development programs such as Apollo, the Space Shuttle, and now the Space Station, it has been common at the PDR phase of development for designs to be incongruent with available resources. Actually, I would be very surprised if the demand for Station resources at PDR fit within the allocated resource envelope. It is the process of careful examination and combination of duplicative or marginally beneficial requirements and/or design solutions which will optimize the program. This process will not be completed without controversy and considerable stress. It will, however, in the long run, force every aspect of the program to justify its existence against all others, so that we can design and build a Space Station which will meet the greatest number of requirements at the lowest possible cost. In sum, what we are seeing in Space Station is typical of programs at this stage of

development. As this process progresses, I can assure you that NASA will keep this and all appropriate Committees fully informed of our progress in these areas.

I would like to take this opportunity to say that it is extremely important that the momentum of the Space Station Freedom program continue. The baseline configuration is holding through the PDR process. When we emerge from PDR, there will be solutions to the discrepancies identified, a new reference assembly sequence, and a better definition of Station operations. We will then move into the Critical Design Review next year. However, in order to maintain this progress and to meet the March 1995 First Element Launch date, we need funding stability. This is something the program has not had since its initiation, and which has caused numerous reviews resulting in program redesigns and redirections. As you know, the budget cuts imposed last year forced the program to review its requirements and reduced or delayed some capabilities. The FY 1991 budget request is critical because it represents the first year after PDR, and we expect to need our full funding request in order to cover actions resulting from the PDR. If the reductions in Station funding included in the House-passed FY 1991 VA-HUD-Independent Agencies appropriations bill are sustained, the program would once again be disrupted. Any funding reduction will affect the schedule and potentially adversely affect our relationship with our international partners. For these reasons, I am hopeful that this Committee will support our proposed FY 1991 budget requirements.

Madam Chair, I thank you for the opportunity to outline for you our progress in these matters, and now would be pleased to respond to questions.

For Release
July 6, 1990

Sarah Keegan
Headquarters, Washington, D.C.
(Phone: 202/453-1547)

HST INVESTIGATION BOARD STATUS REPORT #1

The Hubble Space Telescope (HST) Optical Systems Board of Investigation met for the first time July 5-6, 1990, in Washington, D.C. After introductory remarks by Dr. Lennard A. Fisk, Associate Administrator for Space Science and Applications; Dr. Lew Allen, Director, Jet Propulsion Laboratory (JPL), and board chairman; and Gary Tesch, Board Counsel, the board heard presentations from NASA Marshall Space Flight Center (MSFC) and Hughes Danbury Optical Systems (DOS) officials.

The MSFC personnel summarized the current status of HST systems. The Hughes DOS representatives gave an overview of the manufacture and test procedures for the HST primary and secondary mirrors and the Optical Telescope Assemby (OTA). The presentations were general in nature due to the impounment of original pertinent data under the provisions of the HST Contingency Plan.

Hughes DOS officials also proposed some near-term options for further defining and characterizing the spherical aberration. Some of the options which were extensively discussed by the board involve data review; others call for testing of existing back-up and prototype hardware and test equipment.

The board heard by telecon the report from the HST Independent Optical Review Panel, concluding that the panel agrees that there is approximately one-half wave of spherical aberration in the OTA.

The next meeting of the board is tentatively scheduled for July 25-26, 1990, at Hughes DOS, Danbury, Connecticut. In the next two weeks activities will be carried out in three areas:

- examination and analysis of pertinent data.
- preliminary interviews of knowledgeble individuals.
- design and preparation of appropriate tests.

The board has modified the impoundment procedures sufficiently to permit the activites above to begin while taking active steps, including independent supervision, to ensure the integrity of the pertinent data and hardware.

At the conclusion of the meeting Dr. Allen said, "The board now has a good base of information from which to proceed with its investigation."

POSITION PAPER OF THE HST SCIENCE WORKING GROUP AND THE HST USERS COMMITTEE

JUNE 28, 1990

SUMMARY

Our groups met jointly on June 27 and 28, 1990, at the GSFC and received reports from key Project personnel about the status of the Hubble Space Telescope, with particular emphasis on the imaging performance. Although the program has clearly suffered a major setback due to telescope optics that are well below specification, we are convinced that the long-term prospects for completion of the science program are highly encouraging. Furthermore, a valuable subset of the scientific program can be executed with the telescope even in its present state, with the result that HST still has the potential to produce many key discoveries in the near future.

HST right now has capabilities that vastly exceed ground-based observatories. Most important are spectroscopy, photometry and imaging at ultraviolet wavelengths, none of which are possible at all from the ground. High resolution visible-light imaging on bright objects will also be possible, achieving to some degree the original fine details expected in HST pictures.

For the longer term, it appears highly probable that the full imaging capabilities of HST can be restored by straightforward modifications to the Second-Generation Scientific Instruments. These are already under development as Orbital Replacement Instruments (ORIs), to be installed in the observatory over the next several years. We recommend that the development of these ORIs be accelerated as much as possible. With determined effort, the WFPC-II camera could be installed in as little as 2 1/2 years, producing images that meet the original design goals.

THE OPTICAL CAPABILITY

We understand that there is approximately one-half wave rms spherical aberration error (2 micron center-to-edge surface error) in the OTA wavefront, leading to images that fail to meet the Level I 70% enclosed light specification by roughly a factor of 7. The observed image radius is 0.7", versus a specified radius of 0.1". For certain focal positions, the images possess sharp cores (~0.07" FWHM), so that at some level the high spatial resolving power of HST is preserved. However, these cores contain only ~15% of the light, the remaining light being dispersed over a wide halo comparable in size to ground-based images. A summary of what capabilities for science are allowed by these image properties and what can be done to recover the full Level I performance of the observatory is given below.

THE SCIENTIFIC CAPABILITIES

HST is an extremely versatile observatory with many modes of observation. Loss of image quality has damaged some of these modes, but many remain wholly or largely intact. Temporarily being able to use only certain of these modes will not alter the fact that we will still be able to do forefront science 100% of the time, but the initial scientific emphasis will have to be different. The number of programs that can be done with the HST has always greatly exceeded the time available for their execution, and this remains true even with the telescope in its current state.

The near-term observing plan will now have to give greater emphasis to ultraviolet imaging (FOC), ultraviolet spectroscopy (FOS and GHRS), and ultraviolet photometry (HSP), plus the use of bright core images in visible light (WF/PC and FOC). These, plus the ongoing astrometry program (FGS), will easily occupy all the time available and will return scientific results of great interest and utility. The fulfillment of the original imaging programs will still be possible, but will largely have to be scheduled later.

These near-term programs are possible because HST, even in its present state, has unique capabilities that cannot be matched anywhere, either in space or on the ground. The core of the sharply

focused image can yield sharp pictures for bright, high-contrast objects such as stars and galactic nuclei. The ultraviolet spectroscopic capability is still largley intact, although some trade-offs are now involved. Obtaining spectra at the planned spectral resolution and desired signal-to-noise will be possible, but the targets will have to be brighter, or the exposure times longer. Spectra of faint targets should also be possible, although with some loss of spectral purity. Fortunately, many programs of the HSP will not be impacted, and the astrometry capability of the FGS will apparently not be compromised at all. Realizing these capabilities will require some new effort; for example, it will be necessary to revise target acquisition methods for the small-aperture instruments and to develop image deconvolution algorithms for the cameras. However, these are not major tasks.

Most encouraging of all, it should be possible ultimately to realize the full capability of the HST through the use of the Second-Generation Scientific Instruments (SIs). The WF/PC-II instrument that is currently planned for flight some 3 years after launch has an optical design that will permit complete correction of the errors in the OTA. The other two new Scientific Instruments, both already in development, will also be able to correct simply for the limitations of the telescope optics. The NICMOS instrument will extend the wavelength range of the HST and open up a new window to infra-red observations. The STIS instrument will expand the spectroscopic power of the HST by at least an order of magnitude beyond the goals for the first generation of spectrographs. Completion of all three of the Second-Generation Instruments is now clearly more urgent than ever.

CONCLUSIONS AND RECOMMENDATIONS

While some of the important scientific goals of the Hubble Space Telescope are currently not achievable because of the spherical aberration in the telescope optics, other unique scientific goals do remain viable, and HST therefore still has the potential to produce many important discoveries during its first years of operation. The original goals for the 15-year mission of the HST continue to be achievable. We therefore recommend that all necessary actions be taken to insure that HST will operate as productively as possible in the short-term, and that activities directed at restoring full capability over the long-term be pursued vigorously. In the short term, this means that on-going HST operations must be fully supported and that the telescope and instrument performance evaluations and analyses must be continued. We also need to adjust to the larger images by developing new target acquisition techniques and by modifying various other capabilities as indicated by the results of ongoing studies.

For the longer term, it is clear that the full imaging capabilities of HST can be restored by suitable modifications to the Second-

Generation Scientific Instruments, which are planned as Orbital Replacement Instruments (ORIs), to be installed in the observatory over the next several years. We recommend that the development of these ORIs be accelerated. Finally, we recommend that the first Maintenance and Refurbishment Mission, which will install the WF/PC-II in place of the original WF/PC, be directed to proceed as expeditiously as possible, with the goal of being completed in less than 2 1/2 years rather than the planned 3-year schedule.

By way of conclusion, we would like to emphasize that an enormous number of technically difficult challenges involved in the design of HST have been successfully met. These include the basic smoothness of the optics, the high degree of accuracy required from the Pointing Control System, and the proper functioning of a suite of complex scientific instruments, to name only a few. In comparison to the huge investment already made in HST, the effort involved in correcting the optical aberrations is fairly small. In comparison to the planned 15-year lifetime of HST, the few-year delay until delivery of WFPC-II is also small. With this perspective in mind, we feel it is important to keep our eyes on the long-term future and work diligently to realize the full potential of the observatory, which is still a fully viable goal.

For the HST Science Working Group,

Albert Boggess

For the HST Users Committee,

Arthur Davidsen

NASA MANAGEMENT

Senator MIKULSKI. Thank you, Admiral Truly.

We are now going to move to questions. We are going to follow the 10-minute rule. The Chair will also abide by that rule in which we will have our first round of 10 minutes. Then we will do another round after that. At that time we will hear from Mr. Beggs, who is now in the private sector but was the NASA Administrator from 1981 to 1986, during this crucial Hubble time. He has agreed to testify.

Also, we decided not to hear from General Allen today because the Allen report is underway. And we know that General Allen has already testified on the Hill. Rather than having General Allen come up continually to the Hill to tell us what he was going to do, it was our committee's decision that General Allen ought to be out there completing the investigation on which he was given responsibility.

It will be the intention of the subcommittee to hold additional hearings on the Hubble during which General Allen can give us progress reports and so on.

I just wanted people to get a sense of what we are doing today. Today is Hubble and then some of the broader issues.

We also want to note that Senator Leahy of Vermont has joined us. I am going to ask him, if he has an opening statement, to give it when he asks his questions.

Now, I want to go on to my questions.

First of all, Admiral Truly, thank you for your testimony. Actually since you have become NASA Administrator with the Hubble problem, I have found you to be extremely candid in conversations with myself and with the committee as we have done our business. We have a great deal of respect for you, Admiral, and we think that you are trying to get a grip on this.

It is true, you have inherited something that suddenly has converged upon NASA and which NASA seems like it is not only under a cloud, but under a full Moon with these three issues.

What we hope to do today, is again, to get more of the Hubble issues, the type of questions Senator D'Amato raised. But also I intend to raise the questions that your critics have made to give you an opportunity to comment on those. If the criticisms are not valid for you to be able to rebut them. And if they are valid, to be able to talk about plans for dealing with those.

I think this subcommittee is committed to a space program that is achievable, affordable, and takes us to the 21st century.

Now one of the things that comes up recently and also in the past about NASA is this issue of management. There are those who say that after the *Challenger* accident we missed the opportunity for a top-to-bottom review of NASA at that particular time, and that NASA's way of handling problems is management by disaster, that there is a problem like a *Challenger* or a Hubble or whatever, a team is sent in to do the investigation and we fix that particular technology.

The question becomes is it flaws in technology in a high-risk program or is there essentially a problem at NASA. Your critics, and particularly in this book on the Hubble space telescope by Robert

W. Smith at the Smithsonian, says that there is a dynamic at NASA that continually underestimates project costs when it starts a mission, overestimates the capacity of technology and for us to invent technology, and therefore, we have serious problems later on in both performance and then credibility.

That, by way of introduction, says to me, Admiral, you are about to appoint a blue-ribbon commission at the request of the Vice President and which you yourself wanted to do. Could you tell us what will be the purpose of that commission? Then, does it do this top-to-bottom review that is often discussed?

You can comment on the whole thing. I think I have laid out every headline, and quite frankly, at times some of my own thinking on this.

NASA RESPONSE TO "CHALLENGER" ACCIDENT

Admiral TRULY. Let me first go back to after the *Challenger* accident, and what you said was a perception, or what somebody has said was a perception, that we should have done more than just look at the *Challenger* accident and we should have looked at a top-to-bottom review of the agency. Well, I do not know where these are coming from, because that is exactly what happened.

There were two things done after the *Challenger* accident. I went into the Office of Space Flight, in the organization that Dr. Lenoir now runs, and over a period of time, in addition to fixing solid rocket motors, we looked at the space shuttle organization, from top to bottom, the relationships of the centers to the program at all levels, at the relationships of the contractors that we had. For example, in the major study down at Cape Kennedy on the shuttle processing contract, and throughout that entire program, and the program that we have in place now is the program that has flown 10 perfect missions in just over 18 months since the first mission after the *Challenger* accident. It is the same program that has this risk-assessment system in it that caught these two hydrogen leaks, and it is the same program that is going to fly the next flight.

Now, I cannot tell you that we have got all the risks out of the next flight or the next 100 flights, because we cannot do that. But that organization is operating and we have gotten acclaim from the safety panels, everybody that has reviewed it; we have had them down there watching us operate. But in addition to that, Dr. Fletcher invited Sam Philips, who use to be in NASA back in the 1960's during Apollo, who had a group to come into NASA and they stayed away from what I was doing in the Office of Space Flight pretty much with the shuttle program.

Now, I briefed them on what I was going to do but they looked at the NASA organization structure. Many changes were made. For example, the appointment of George Rodney as Associate Administrator for Safety and Mission Quality, looked at headquarters organization. And so, we have had a very recent look at the structure of the organization. Any organization will change with time.

AGENDA OF ADVISORY COMMITTEE ON THE FUTURE OF THE U.S. SPACE PROGRAM

Senator MIKULSKI. What is this commission going to do?

Admiral TRULY. When I talked with the Vice President and we talked about setting up a task force, I talked to him for about an hour, just he and I, about this whole situation. Most of our conversation, quite honestly, was about the future. We were not talking about hydrogen leaks or what is going on today in NASA. We were talking about how the NASA of today could somehow become a more robust organization, out in the future when, if this vision and the President's vision and mine come to fruition, the space operations of this country will need to be more robust. And also in a era where space operations are going to become more and more a problem, rather than research, we want to continue to keep the ability for our organization to do cutting-edge technology and research, and at the same time, be able to do these large operations.

We talked about it and he asked me to put together a task force, and I am going to be doing that. I think when we are able to announce a chairman and a few members, you will see that this is not a witch hunt. They are not coming after me or NASA. They are going to try to help us look to the future. You know, the landscape of American technology is changing today.

PATTERNS IN COST OVERRUNS IN NASA PROGRAMS

Senator MIKULSKI. Admiral, I understand that. Also, the questions we are asking of NASA, I think could be asked of many of the Government agencies. Senator Garn and I have conferred. We have schools that do not teach. We have programs that we fund where there is very little outcome and so on.

But we chair this subcommittee and, therefore, there is this issue of a pattern at NASA in all administrations that underestimates cost, overestimates technology, and then we find ourselves, as appropriators, trying to grope with that. And now, of course, we have very stunning possibilities of new start that have big price tickets to it, and the questions are—we never know exactly what we are getting into. But Hubble was $400 million and it cost $2 billion. Space Station Freedom was going to be $8 billion, and now it is $37 billion. These are the questions that we are faced with as appropriators, and also that the American people are asking. Is there going to be any look at this so that we get authentic estimates?

Again, this is not a criticism of you, Admiral, but this seems to be the pattern, and this is one reason why there is a credibility concern.

Admiral TRULY. You know, one of the hardest things that any organization that does research and technology, and does things that have not been done before, is in estimating costs and schedules. I do not think there is anything fundamentally wrong at all with our ability to do that, but when we get into problems that are tougher than we thought, we have to get around those problems. And that combined with programs where it is hard, even despite this subcommittee's fighting for us to get some funding stability, it is a difficult outcome. But it is not a—I can say this, it is not an effort on NASA's part to come to the Congress with a lower number or faster schedule than we believe we can achieve. I do not know if that warning light turned me off or you.

FACTORS INVOLVED IN COST OVERRUNS

Senator MIKULSKI. It turned me off, but it is going to turn him on, and I do not know which you want to cope with right now. I am going to come back and then get into the more specific testing of the mirrors.

Senator Garn and then Senator Leahy.

Senator GARN. Thank you. First of all, let me make a comment about cost. There is, no doubt, facts are facts, and virtually every program has cost more and taken longer than was intended. But I think the first thing we have to do, and maybe I am on the wrong side of the table, Madam Chair. Maybe I should be over there. I feel like I would rather be testifying than questioning.

Senator MIKULSKI. Well, you are, Senator. [Laughter.]

Senator GARN. Well, which ever way.

Senator LEAHY. Jake, you have never let being on this side stop you from testifying before.

Senator GARN. That is true. But when I look at it, if you deflate it to whatever your dollars, or course, that makes it look a lot better. First of all, with any Government program you have got to do that. But I would say that the cost overruns in NASA on their programs, if you look at them, are rather small compared to virtually every other agency of the Government. I have been on this Appropriations Committee now for 13 years. I look at what the administration has done since January. All they were was $60 billion off on estimates of the budget.

My point is that the Government, in general, has a total and complete record, at least the 16 years I have been here, of underestimating the cost of running Government in areas that are nontechnical, that should not be hard to figure out. And so, I am not excusing the fact that we have had, in many cases, underestimates, but they have been closer than most other Government agencies and in an area where it is difficult to decide what the cost would be.

And the third point is, that many of these costs would be much lower had Congress funded the programs and kept them on schedule, and a lot of the cost increases are delays caused by under funding by Congress.

NASA ASSESSMENT OF SPACE STATION EVA

Admiral, let me go to the issue of the space station and EVA's, because I want everybody to be sure and hear what you said about discovering problems in the design review, because every time something like this comes out, it is as if the press has discovered something new and terrible and they have got to make sure the whole world knows about it.

No. 1, it is true that NASA created Fisher-Price to do exactly what they are doing, is that not correct?

Admiral TRULY. That is correct. We found the problem. We decided to cure the problem when we created Bill Fisher and Charlie's team to go define it for us.

Senator GARN. So, this is part of the process to discover if there was a problem, and the answer is yes, there is a problem.

Admiral TRULY. That is correct.

Senator GARN. And the reason for that is so that you can say, all right, 3,800 hours a year, or whatever it is, is obviously way, way excessive. We cannot live with that. So the process is now to find out how do we make changes in the hardware of the station, how do we minimize maintenance, and my expectation from past performance is that obviously, you would not live with 3,800 hours, if that was the latest figure of EVA, that that has to come down, and it will. And there would be, as you say, you are only 10 percent along in the design, is exactly to reduce that. So, first of all, you cannot solve the problem unless you define it.

So at your request, the problem has been defined. It is excessive. Nobody would live with this. I would not want to vote for a space station and money that required that much maintenance. So, we will find that design process is already going on and we will say, OK, what do we change? How do you make this difference so that it requires less maintenance and less EVA? I realize I am leading you, but I am doing that deliberately because I would like people to understand the facts of the process rather than this sensationalism and inflammatory reporting that we continue to get. Am I correct or am I wrong, or what?

Admiral TRULY. You are absolutely right. The reason we run a preliminary design review, and over the years in the space business and in other aircraft production and so forth, the reason that is done is because our experience shows us that if you find the problems early, and identify them early, and make the tough decisions. And there is a lot of controversy inside the organization. If someone really wants this blivit, but it weighs 10 pounds and you only have 8 pounds to give him, and you have to make the tough decisions to balance the program. That is what happens in a preliminary design review.

PURPOSE OF SPACE STATION PRELIMINARY DESIGN REVIEW

Senator GARN. I would also expect then that the next conclusion is that we will find other things of this nature, that that will be part of the process that we will find problems with the space station, because you cannot design it all at once and say here it is, let's put it up there. It is a very difficult process. And I would expect, at least, personally I would think, that we will find problems of this order in other areas as we go through this preliminary design review.

Admiral TRULY. I would be stunned if we do not. That is what it is for.

Senator GARN. That is the point, and I wish people would be kind enough to listen to that so that the next time you find one and report it openly, that it is not some big exposé of, my god, we have found another problem at NASA, as if somehow these reporters with all the technical background they have, have discovered something under a rock someplace. I want to make that point very, very strongly. This is part of NASA's process to understand the problems before we start putting things up, and then correct them so that it is a workable system.

EXPERIENCE CONCERNING SHUTTLE LEAKS

I would also like you to amplify, just a little bit, the process of a shuttle launch so that people understand why those leaks were found. I do not know whether you remember or not, but one of the delays in my flight was for a leak in the 17-inch line. So this is not a new situation. The final cause of the delay of mine and the switch to *Discovery* from *Challenger* had to do with a satellite that was not working and was already in the cargo bay, and nothing wrong with the shuttle. But we had one delay. It brought no great publicity because we canceled. As a matter of fact, my flight was scheduled February 20, 1985. We flew on April 12. So again, that was a normal process of NASA.

But if you could describe, just briefly, the process of a shuttle going out to that pad and the checks it goes through.The checks are working is the point I am trying to make. By discovering those leaks, rather than being some great tragedy, the process worked. If it did not we might have killed some astronauts.

Admiral TRULY. I will be very brief. The process starts about 1½ years ahead of time when you start planning, doing all the planning for the mission, training of the crews, and since the orbiter that is going to fly on a given day just landed from another flight 3 or 4 months before that, when it returns to the hangar, we have a careful list of tests that we begin doing on that orbiter, in addition to reconfiguring the payload bay or the orbiter, to be configured for that next mission.

At the same time, coming from plants out in Utah or down in Michoud, the solid rocket motors and the external tanks are tracking along. And the tank, the shuttle, and the orbiter all meet a few weeks before flight in the vehicle assembly building [VAB]. You do tests there. The umbilicals, for example, are checked out and torqued down in the VAB. The vehicle is taken out to the launch pad.

About 4 days ahead of time, we actually enter the launch count and we start a process of checking methodically, a predescribed series of items. Because of the size and the capability of the shuttle, the first time that those umbilicals ever see cryogenic hydrogen or oxygen is out on the pad when they are hooked together. So that is the first time that you actually have the ultimate test.

You then count the vehicle down. You finally get close enough that humans cannot keep up with the checks and you turn the process over to a computer a few seconds before lift off. You always have the ability to scrub, but there are so many things going on. It is a very, very complicated business. We check, recheck thousands and thousands of component parts, and we do that. And we did that 10 times in a little over 18 months in the 10 perfect flights we have flown since *Challenger*.

POST-"CHALLENGER" SHUTTLE SOFTWARE CHANGES

Senator GARN. As a result of the Rogers Commission report on the *Challenger* accident, your computer software was changed considerably as far as the launch criteria, compared to when you and I and Bill flew. Is that correct?

Admiral TRULY. Yes; as part of the process that did not have anything to do with the hardware itself, we went through all of our

criteria, all of our launch probabilities, all of our mission rules, all of the ground software, all of the flight software, independent software verification, and so forth. So the management, the hardware process, the software planning and processing, the training program was looked at while we were down.

Senator GARN. Weather criteria were changed.

Admiral TRULY. All the weather criteria were changed. That is why this time when we had two hydrogen leaks, which can be just as explosive as the solid rocket motor, we did not go down for 3 years. We did not have to go recheck all that. We knew precisely what we were looking for, and the team went in there and found it, and we are going to be flying in a couple of weeks or a few weeks.

Senator GARN. Again, to summarize or at least make my point, the process worked. That is why we found the leaks, and that is why I have such a difficult time understanding all of the criticism for a process that was dramatically changed internally at NASA. There is no doubt that my flight would not have flown under today's criteria. We launched through a solid overcast, as you remember, 12,000 feet and so on. So the criteria has been dramatically changed or we would have had more than 10 missions off probably by now.

But again, I have to make the point and I recognize maybe I am on the wrong side of the table, but somebody has got to talk about some facts. Somebody has got to defend the facts and talk about the real situation. The process worked, and as a result we have two birds sitting on the pad to be fixed so that we can make them as safe as possible for those crews. Thank you, Madam Chair.

Senator MIKULSKI. Thank you, Senator Garn.

Senator Leahy.

PUBLIC RELATIONS VERSUS POLICY CONCERNS

Senator LEAHY. Thank you, Madam Chair. I would like to compliment you on having these hearings. I think that they are extremely important. The Hubble space telescope has raised questions in a lot of people's minds. I certainly hear them when I go home each week to Vermont as I go around my State. You think of a photographer who is faced with a once in a lifetime chance of taking a photograph and he forgets to take the lens cap off. It was supposed to be a window to the universe, and it has turned out to be a mirror on someone's carelessness.

I realize it predated the panel. here, but the concern is the same. I do not question that we have, in the United States, an important role in space. Of course we do. But I think before we expand our horizons too much, we ought to fix up the systems at home. When you spend $1.5 billion on a telescope in space and it sees only as well as the best ground-based systems, you have to ask questions. Maybe things are better as some of the testimony has been here today.

I know when I came here 16 years ago, I came as a very strong supporter of NASA. It was almost an article of faith.That support has been sadly shaken, and my faith has certainly been sorely tried and tested in it. Over that 16 years, I get the impression more and more that NASA is motivated by the public relations or what pho-

tographs well rather than by what its scientific mission should be, and many, many times the public relations outweighed the capabilities, or the public relations outweighed the real mission.

We seem to be going more, in the past few years, by publicity considerations than by policy. Look at the space station. More and more it seems to be a project looking for a mission rather than the other way around. This New York Times article says 3,800 man-hours of maintenance would be required each year, instead of 2,200 hours that were predicted. Is that the final number or is it going to just keep on growing? Is it going to get bigger?

Every time I have had a briefing on the space station, boy, it changes, I go back to my files and bring out all these great schematics and pictures and all what it is supposed to do. Do you look at something 10 years ago and look at it today, and it is entirely different.

I realize there is evolution in these things, but it is going to take a couple of years once the final go ahead is given. That surprises me that it changes so much. I realize we are here to talk about the Hubble, but I think if you put Hubble, and put the space station and put the concerns about it, I think that some of your strong support you have had in the past has probably taken for granted, at least in some areas that should not be taken for granted, not mine for example. Some of the support that I felt came almost automatic, now has become very skeptical and would require proof all the way along.

RESOURCE REQUIREMENTS VERSUS MISSION CONTENT

Admiral, you talked about perhaps 8 pounds of resources and 10 pounds of mission. I would suggest that poundage is considerably further apart than that. The resources are going in one direction and the mission, however defined, is going in several directions, each one requiring a lot more. Senator Garn has said you were responding openly and I appreciate that. But I would hope that when General Allen's report comes out, it will be exactly that.

I have warned in the past, I have been to a number of briefings where NASA has had one problem or another and has come up to the Appropriations Committee, the Intelligence Committee or whatever one I may be on and say we must tell you this in a closed-door session. And you find out it was a closed-door session not because we are saving America's secrets but, in at least some instances, we are saving the embarrassment of people who just plain screwed up. Again, I am talking about things in the past, so I would encourage you to do otherwise and be very much in the open.

If we find glitches, and do we find glitches as we go along? Of course. Everybody understands that if you're pushing the art of the possible that there are going to be glitches. But I have to ask, on this case, if the glitches could have been found on Earth. And I would suggest that you find not just why they were not, but is there a systemic problem in NASA so that it is not just this. It may be a shuttle, it may be another kind of launch vehicle or any vehicle you might want to send in space. Has the same mistake been made?

HUBBLE SPACE TELESCOPE COST ESTIMATES AND TESTING

I just read a summary of Smithsonian Institution's book by Robert Smith on the Hubble space telescope. I intend to read it more thoroughly, as I suspect a number of people in NASA are. I would be interested if you have any reaction to that book itself.

Admiral TRULY. Yes; I have read that book. I think it is an excellent—now, I cannot comment as to the accuracy of any of it because I was not in the program. But I think it is a very well-written, scholarly analysis of the dynamics of a large program that takes years to develop. Whether it is accurate and whether people that worked in the program would agree with it, I do not know. I enjoyed it though.

Senator LEAHY. One of the things it talked about is the low-balling of budgetary needs. And I have made this complaint over the years to NASA and to other agencies who are very, very eager to get a particular program and will come in on sort of the camel's nose theory budgetary process. And that is they will come in and they will say, OK, it is going to cost x hundreds of millions of dollars. Get us enough into the program until finally, about 3 or 4 years down the way, they say, you know, by the way, it is going to cost several billions of dollars, but we spent all this money. You cannot stop now.

Two things happen then. One, often—and with NASA usually—the program has continued but everybody is so frustrated by the sudden realization of the full amount, then underfund the full amount needed and shortcuts are taken. Is that basically what has happened with Hubble? Is that one of the reasons why it was not tested?

Admiral TRULY. I think the answer, and I would let Dr. Fisk answer it in more detail, I think the answer is today, that we do not know. We do not believe, however, that the testing that failed us, and somewhere testing had to fail us in this. There is no question about it. And as you mentioned, we will take a look as to what was the situation and what lessons are to be learned by that. I certainly do not believe it is going to turn out to be anything systemic in today's NASA, because—as a matter of fact, from the Hubble space telescope project lessons, we totally revamped that program in 1983 when Administrator Beggs was the Administrator. But unfortunately at that time, the mirrors were already developed. But I certainly do not think it was systemic. There was a testing failure, but we cannot tell you now what it was because we do not know precisely what happened as of now. And Dr. Allen will have to determine that.

Senator LEAHY. The reason I say this, and I talked about the underselling and so on in that same book, there is a line that says to a significant degree the crisis of late 1982 and early 1983 was the outgrowth of the overselling and underfunding of the mid-1970's. I mention that, and I will have some specific questions which I will follow as we go along in these hearings. And I realize you are having a series of these things, and I would much prefer waiting until General Allen's report is finished. And then I will ask questions based on that.

CRITICAL SUPPORT OF NASA GROWING

But just to say that while you will have, both in the House and the Senate, some really uncritical supporters, enthusiastic supporters of NASA, you are gaining a far larger number of critical supporters. There were far more Members of Congress who were willing to take NASA on faith in years past who now want to have it proven to them what they are saying.

Some may think that that is an unfortunate thing for NASA. I might suggest, because of some of the things that have happened in the past, it might be the best thing for NASA. It will be more concerned about what is the art of the possible and what most reflects the needs of this country, and less what might be the art of the flamboyant or congressionally or administratively popular. And I would hope that with that we would go forward.

Admiral TRULY. Might I make one quick response? You did cover a lot of things. I am quite willing for people to be critical of NASA in the sense of critical from the point of view that we have a program. Even though it is not a large percentage of the Federal budget, we spend a lot of money in the space program. And I am quite willing to be accountable and for NASA to be accountable for good management and for mission success. I do think, though, that we should be careful about that criticism and make sure that it is based on facts and not on perception of a combination of different problems that did not have anything to do with each other.

Thank you, sir.

Senator MIKULSKI. Senator Gramm.

CUTTING-EDGE TECHNOLOGY

Senator GRAMM. Madam Chairman, thank you. Admiral Truly, I appreciate having an opportunity to visit with you today. I think it is very easy for Congress to look at the problems with the Hubble and the problems we had with the shuttle fuel leaks, even though Senator Garn, our distinguished colleague and former astronaut, tells us that those are problems that we have already learned how to fix, and be very critical.

But in reality as I see it, we have only two choices and I want to be sure we remember that in trying to deal with a very real problem and one we have every right to be unhappy about, and that is failure. The American people do not pay you to fail. I think only in Congress would you get paid for that purpose. [Laughter.]

But in any case, I think it is important that we look at the alternative and I think the alternative is 1970's and 1980's technology. And I think by doing that, that we can be guaranteed very few failures that are going to get in the newspaper and on television. But yet we can also. be guaranteed a second-rate space program. My feeling is if you are going to deal with 1990's and 21st century technology in 1989 and 1990, that you are out there on the cutting edge of technology. And whenever you are doing that, you are subject to having problems that you have to go back and fix.

I guess my only criticism is, and since we are talking about lots of money, and spending the taxpayers' money is a serious subject, our situation in looking at your telescope test results is sort of like a weatherman who has all of his machines. He has his radar, he

has his printout, and they all told him the Sun was shining and he went on television and announced it. The only problem is he did not look out the window to see if it was raining. [Laughter.]

I guess maybe one of the things we ought to learn from this is that with all the sophisticated tests, and I know we are talking about a different kind of telescope than I used when I was a kid, but there is no substitute for looking through the telescope to see if, in fact, you can see something or if it is in focus.

But I would like you to respond to this general issue about cutting-edge technology and the problem that is entailed in trying to operate on the cutting edge of technology. If you have—just give me a burst transmission on it, a summary of what we are looking at in terms of fixing the problem, how well you have the problem identified, how simple the fix is; within our current timetable, when are we looking at getting it fixed; and then obviously, how much money is it going to cost.

ONE-OF-A-KIND VERSUS MULTIPLE NASA PROGRAMS

Admiral TRULY. If I may, let me answer the first part of your question and then ask Len Fisk to talk about the science we are getting and the fixes that are in process.

You talk about using old technology and how that would be a lot more straightforward and the problems of programs that reach out into the future and do things that have never been done before, and you are exactly right. And as a matter of fact, as we were talking earlier, I think this is a good example of the difference between programs that are doing one-of-a-kind things that do not have funding stability as compared to programs that are doing things that are more routine and have funding stability.

We have on the one hand the Hubble space telescope, that whether the mirror was perfect or not, it had a cost growth and a delay for various reasons. It was a one-of-a-kind vehicle. It had its funding problems with the Congress in those years. And unfortunately we are here at this hearing today because of a problem that occurred during that process.

In 1987, after the *Challenger* accident, the Congress funded a new orbiter to replace the *Challenger*. It was funded with money all in that year. We did not have to come back to Congress each year to ask for $312 million or $325 million, and do that; we got the money up front. We are building that orbiter in Palmdale. We are going to roll it out in May 1991. It is going to be under cost, on schedule, and it is going to be built with all the changes in it that we had since the last time we built an orbiter. And I do not think there is a better example of those two things, one—something we know how to do.

Senator GRAMM. That is the fourth of the kind, right? In other words, this is the fourth one we have built?

Admiral TRULY. Yes; it is the fourth orbiter we have built.

Senator GRAMM. So your point being, if we had built four of these we would have it right. But if we are just going to build one with new technology——

Admiral TRULY. My point is that having built four and having gotten—it was the fifth. I am sorry. My point is that having fund-

ing stability and having done it before, it was a job that was easier to manage. Not that it was easy to manage building an orbiter. It is no straightforward thing. But comparing that to a far-out program that does not have funding stability—and you can name as many as I can and probably a lot more—it is a different management challenge. And it does not mean that when you fail, you are no good at managing. It means that is the nature of this business. And that is true in other high-technology agencies.

CURRENT HUBBLE CAPABILITY AND FUTURE REPAIR PLANS

Might I ask Len to comment on the science?

Dr. FISK. Let me divide this up into two parts: what Hubble can do today and how we fix the problem. Hubble today is a very capable telescope in the ultraviolet, and let me give you a quantitative measure of that. It is a factor of 100 better than any previous ultraviolet telescope that has ever flown. It is a factor of 100 in spectral resolution. It is a factor of 100 in sensitivity better. And it can do imaging in the ultraviolet, which is something we have never attempted to do before.

That capability exists today with the mirrors—spherical aberration in them. They can do spectroscopy today with essentially no degradation. They can do photometry today with essentially no degradation.

It is degraded in visible light observations. That is where the fuzziness of the spherical aberration affects us the most. We are about comparable to a very good ground-based telescope on a good night. But we are not better, which is what we intended to be.

But as Admiral Truly said in his opening remarks, the saving grace here is that the aberration in the mirror is so perfect. They built a perfectly wrong mirror. But that perfection in the aberration makes it very simple to correct.

Essentially what you do is in the next generation of instruments which are underway now—they are in the program, they are in the approved budgets for the Hubble space telescope—you make a correction in the mirrors in those instruments, which essentially is equal and opposite to the spherical aberration that is in the primary mirrors on the telescope. End of problem.

We have had this reviewed by teams of optical experts and they agree with our conclusion, which is we can take the aberration out completely. We can correct for it completely and have Hubble meet the original specifications.

The current plan calls for the first of those second generation instruments, the second generationwide field planetary camera, to be on orbit in June 1993. And of course, that is essentially 3 years into the life of a 15-year program. And after that point, Hubble is back to specifications.

Senator GRAMM. Thank you, Madam Chairman.

Senator GARN. Madam Chair, could I just make a technical correction? It is not important. But as I was thinking about your answer to No. 4, this is No. 6 if you count *Enterprise,* which did not fly, and *Atlantis* and the others. So the one we are talking about is No. 6, not No. 4.

Senator GRAMM. See, that is a perfect example. Fifty percent error is good enough for Government work.

Senator MIKULSKI. Senator Gramm, have you finished your questions?

Senator GRAMM. I am through, Madam Chair.

Senator MIKULSKI. We are now going to go into our second round, and we are going to essentially have each Senator take 5 minutes, which means we are not going to be able to go through all of our questions.

I would like to focus now on the Hubble testing. I am going to ask my questions to you, Admiral Truly, and then either you or——

Senator LEAHY. Madam Chair, if I might, just to save time, if I could have permission to submit my questions.

Senator MIKULSKI. Without objection. Thank you, Senator.

HUBBLE TESTING

Now on to the Hubble telescope. First of all, Admiral, did anyone check the assumptions on which the design was based? And then did anyone check the assumptions on which the manufacturing was based? In other words, did we sweat the details or did we just assume that the assumptions were correct?

Dr. FISK. The design was checked by many, many people. When you design a telescope like this, you essentially have a prescription, as you would in the case of your own eyeglasses. That was a prescription that was shared widely throughout astronomers in this country, including all the people building instruments. Anyone who was building an instrument for the Hubble space telescope needed to understand the design in detail in order to build their instrument. And so I would guess literally hundreds of people checked the prescription.

Senator MIKULSKI. What about checking the assumptions of the manufacturing?

Dr. FISK. That we are less clear on. When you make a mirror like this, one of the things you have to build is something called a null lens, which essentially determines the shape of the mirror. We are also confident that the design of the null lens was adequately checked. But what we are less comfortable about—and that is where Lew Allen's panel is digging hard at the moment—is how adequately the checks were made on the construction of the null lens and, therefore, on the construction and the testing of the mirror that resulted from it.

Senator MIKULSKI. Well, you can see where I am heading, that really, when we use the example of eyeglasses—and Hubble was to be the greatest eyeglass in space—either the ophthalmologist who wrote the prescription was flawed in his assumptions, which is the design, or the optician who filled it, which is the manufacturer, was flawed. That is why I asked about the assumptions.

Now there has been a lot said about the tests, what kind of tests, et cetera. But on the tests that NASA used, did anyone test the testing equipment? Or do we assume, again, that the testing equipment was OK?

Dr. FISK. Again, we need to let Lew Allen's panel answer that. But let me give you my understanding of it as of today. As part of the construction of any mirror, you do continuous testing. But the testing is done with the null lens, which is what you are using to determine the shape of the mirror in the first place. So that null lens is an integral part of the process and many tests are done with it. Of course, if you have an error in your null lens, you not only are manufacturing the mirror to the wrong prescription, but you are also testing it and proving that case.

NASA PRACTICE REGARDING TESTING

Senator MIKULSKI. Could I ask about the pattern and practice at NASA? Is it the pattern to test the testing equipment?

Dr. FISK. Absolutely, absolutely. As I think Lew Allen said the other day, and I will quote his statement, I am sure that when we are done with this, someone is going to be very embarrassed.

But please rest assured that the tests that are done on any spacecraft are designed to be independent tests. They are designed to be independent of the equipment that was used to manufacture it. And there are often several different ways to do the test and they are designed to be independent.

HUBBLE SPECIFICATION TEST

Senator MIKULSKI. I will come back to that if my time does not run out, Dr. Fisk.

This then takes me to another question. There are those who say that the Hubble tests that were conducted were to test to see if Hubble met specifications. They did not test to see if Hubble worked at all. Could you comment on that? And are those criticisms justified?

Dr. FISK. I think, with the virtue of hindsight, what we are liable to discover here is that all the tests were designed to see whether Hubble could meet its specifications, which were, in fact, extremely rigid. So if you want to determine whether you are building a mirror with a surface of one-fiftieth of the wavelength of light, which is some number on the order of one ten-millionth of an inch, then the only valid test that would do that is a laser interferometry, which is essentially to say the null lens. It does not appear that anyone said, am I even close? Am I within several wavelengths of light, which would have been a much simpler test to do.

Now we all sit with the virtue of hindsight when we say that because there was no expectation on the part of the people doing the manufacturing that they were off by anything like several wavelengths of light. They were looking to build a mirror that was accurate to within one-fiftieth of the wavelength of light.

DETECTING HUBBLE'S FLAWS

Senator MIKULSKI. There are those who say there could have been tests that would have done—and I know one of the things along the course of Hubble is that some of the tests proposed would have required a facility quite expensive. Decisions were made for budget reasons.

However, Dr. Roger Angel, director of the Steward Observatory in Arizona, said a test to detect Hubble's flaw could have been done at almost no cost. He said that in Newsweek a week ago. Dr. Bob Brown, former chief scientist for Hubble who is now over at the Space Telescope Science Institute, said that NASA could have built a cheap observatory on the ground and aimed Hubble's mirrors at a star and the defect would have been apparent.

Now, gentlemen, we are laymen. We do not have high degrees in high physics. What would you say to that? Are those accurate? That, in other words, there were reasonable, low-cost tests available?

Dr. FISK. Let me try and explain this in a straightforward way here. We know now that Hubble's mirrors are in error by several wavelengths of light. Now, if you wanted to define a test that would have seen whether Hubble's mirrors were accurate to several wavelengths of light, there were a whole series of simple, low-cost tests that could have been done. There are ones that mirror builders in the 1930's, long before lasers were invented, that could have done those kinds of tests and found that we were inaccurate by several wavelengths of light. So there are simple, low-cost tests which could have detected Hubble's spherical aberration. No question about it.

However, if you wanted to say, could you have defined a test, a simple low-cost test, that would have seen that Hubble met its very rigid specification, which was less than one-fiftieth of the wavelength of light—let us say that is a factor of 500 better than the kind of aberration that we have, or a factor of 250 better than the kind of aberration that we have—there were no simple, low-cost tests that would have seen that we met that specification. But we could have seen that we were—or we would have seen the Hubble error if we had looked in some simple, low-cost way, which apparently was not done.

Senator MIKULSKI. Do you have any reason to know now why that was not done?

Dr. FISK. I do not. I think, again, we have to be very careful in fairness to the people at the time. You know, we know there is an error by several wavelengths, and so we can say why did you not look for it? They were looking to see that they were accurate by one part in a 50th of the wavelength of light.

Senator MIKULSKI. Dr. Fisk, the scientists are quoted—who had worked on a kind of a science watchdog group—are quoted in the papers as saying, we were overconfident and we were overworked.

Dr. FISK. I think the former might be true. I am not sure that anyone should ever claim that they are overworked on a project of this importance.

Senator MIKULSKI. Well, we will come back to that.

Senator Garn.

Senator GARN. I would like to continue along this same line. Senator Mikulski asked one question or quoted one scientist that said, we could have mounted this on the ground and looked through it. This is an area that I have no background or expertise in at all. But that seems a little bit difficult for me to believe because, if for no other reason, atmospheric distortions. How could you get a fair test looking through the atmosphere?

Dr. FISK. That is absolutely true, Senator. Again, the distinction here is whether you are looking for an error on the order of several wavelengths or whether you are looking to see that you met the specifications, which is to be accurate to 1 part in 50. You would not build a telescope that had a mirror as smooth as 1 part in 50 of the wavelength of light if you were going to look through the atmosphere because the atmospheric distortions would produce fuzziness in your images which were far greater than the distortions in a mirror surface on the order of one-fiftieth of a wavelength of light.

So if you said I am now going to set the Hubble space telescope up and I want to see how it works as a system by looking at a star, I could not have told that it met its specifications because the atmospheric distortions were much bigger than what my specifications were for the Hubble space telescope.

Again, we have to always remember this with Hubble. The driving motivation during the construction of the Hubble mirror was to see that it did not get contaminated. It is supposed to work in the ultraviolet, and that is a very stringent requirement on cleanliness. You cannot have more than one molecule thickness of hydrocarbons or oil on the surface of the mirror. And the project was not even sure, and I think in retrospect did not know how it would clean it if it had that contamination. So anytime any test, any transport of the telescope was considered, the driving consideration had to be, can we guarantee that we do not get this contaminated.

I might add that we are sincerely thankful that they took those precautions, because the science that Hubble is going to realize in the next few years, before we make the replacement instruments, is going to be in the ultraviolet.

Senator GARN. It really surprises me that so-called scientists could make that kind of a comment because I have no background in this area at all. I had my 50-power telescope when I was a kid, but to say you could mount it on the ground—the contamination factor, the possibility of damage, but forgetting that.

People can tell the difference taking their telescope in a lighted area and taking it up on a higher mountain. Same with those little telescopes that all of us had. When I really wanted to see something I used to go up in the mountains of Utah because you were 5,000 or 6,000 feet higher. And even that 5,000 or 6,000 feet less atmosphere, and the fact that there was no interference of lights coming from the city, made a huge difference.

So I do not know who that scientist is, but when the chairperson asked about that I thought, boy, I wonder where he got his degree.

Dr. FISK. Well, some of us said, well, be careful there. Some of us have been so misquoted and misquoted out of context recently, for all I know those scientists did not say that.

TESTING THE BIG PICTURE

Senator GARN. That may be true. Let me ask you another question that is a little hard for me to understand. I have heard the explanation several times. I understand that they did not test the big picture. It was like looking at individual trees rather than the forest. But is what you are telling me that, with their very sophisti-

cated tests, the mirror was within one-fiftieth of a wavelength, and so it was sort of a perfect error. The mirror tested all right for those very fine definitions, so it was in the wrong shape. In other words, that would be like talking about Senator Mikulski's eyeglasses. They were perfectly ground, but they were not right for her eyes. Is that essentially what we are——

Dr. FISK. That is absolutely correct. We have the smoothest mirrors that have ever been built, bar none. So they are smooth to within one-fiftieth of the wavelength of light. The figure, however, of the mirrors, however, is in error by several wavelengths of light. But the smoothness of it and the symmetry of this aberration, of course, is what allows us to correct it.

Senator GARN. So it is a perfect mirror that is wrong?

Dr. FISK. Right.

END-TO-END TESTING

Senator GARN. I also heard you say the other day that in light of all you know now, you still—all the publicity is and most of what I hear of why did they not do the so-called end-to-end test. But is it your opinion that even with what you know now that an end-to-end test was still not necessary? That this monumental goof could have been picked up easily in another area without going to the expense of that?

Dr. FISK. That is absolutely correct. The way you would try and be fair about this is you try and say suppose I was the Associate Administrator in 1980 and I was reviewing the Hubble space telescope, what would I have liked to have done. What I have seen so far is I would have concurred that an end-to-end test was unnecessarily risky from contamination and was unlikely to have revealed that we met our specifications because of the rigid specifications we had. I would like to think I might have been smart enough back then to say, well how do you know you are even close? What is the simple test you do?

POSSIBLE CONTAMINATION PROBLEMS

Senator GARN. With your concern about contamination as far as the operational part of this, nothing to do with the manufacturer, then I would have to conclude that considering the vibration of the launch and the handling of the telescope and mounting it in the orbiter and so on, that on that part of the job NASA and the crew did a remarkably good job to launch something so sensitive, so critical as far as contamination and put it into orbit without any of those problems.

Dr. FISK. There are many success stories on the Hubble space telescope. The really challenging technology, the fine guidance sensors, keeping it clean, making a metering truss to hold the mirrors that did not change under a large variation of thermal conditions, all of those are working very well and are an outstanding engineering success. We have one very fundamental flaw.

Senator GARN. Thank you, Madam Chairman.

EXPECTED COMPLETION OF GENERAL ALLEN'S REPORT

Senator MIKULSKI. Some just general quick questions before we wrap up this panel and turn to Mr. Beggs. When will General Allen complete his report, Admiral Truly?

Admiral TRULY. We have not laid a schedule on him. What we have asked him to do is to lay out a schedule so that he can be assured that he has the time to methodically go through the hardware that is available to them up at the contractor's plant and that we do not destroy the evidence. When we know that schedule, we will provide it to you. And he will be happy to talk to you in the interim or at the end when he is done.

WIDE FIELD PLANETARY CAMERA

Senator MIKULSKI. When is it anticipated that we will be able to return to space and fix the nearsightedness or the cataract or whatever? When do you think that we will have a space ophthalmologist ready to go and who will know what to do when he or she gets there?

Dr. FISK. No later than June 1993. We are asking hard questions at the moment of how fast we can accelerate the wide field planetary camera [WFPC]. The wide field planetary camera, is a very challenging instrument. It is about the size of a telephone booth. And our issue for getting it ready—we can get it ready faster, but it will be technology. It is not going to be funding. It is going to be how many really qualified people are available, how many shifts can they work, et cetera, et cetera.

Senator MIKULSKI. Do we know how to fix it now?

Dr. FISK. Absolutely, absolutely.

Senator MIKULSKI. So why cannot, like three shuttles from now, somebody go up and fix it?

Dr. FISK. The issue is there is a second-generation instrument that is being built and has to be finished. We cannot go up and take the instrument that is out there, up at the telescope at the moment, pull it out, bring it into the orbiter, and replace the little mirrors on that. That is too skilled an operation to perform on orbit.

So we have to have the second-generation instrument ready to go. It is being built as we speak. It is underway now and it was scheduled to be completed by June 1993. The question is can we make that go faster? And the issue is going to be, not money particularly, it is going to be technology. It is going to be how many people can we put on this.

Senator MIKULSKI. We are not going to put a rush job on this.

Dr. FISK. We have got 15 years to get everything out of Hubble we expected to get.

Senator MIKULSKI. Well, we thank you for this first round of hearings on Hubble. We are sure we are going to continue this and the other specific issues that have been raised here. We thank you for your testimony. Of course, you are welcome to stay as we move on to talk to Mr. Beggs.

Admiral TRULY. Thank you, Madam Chair.

Senator MIKULSKI. We are now going to ask Mr. James Beggs to come on up.

Our next witness will be Mr. James Beggs, president now of Spacehab, Inc. He was former Administrator of NASA from 1981 to 1986.

Mr. Beggs, we welcome you and we understand that the time did not permit you to prepare written testimony. We understand that. On behalf of the committee, we thank you for your public spiritedness in agreeing to come and essentially walk us through some of the past. We can read historical books and do hindsight. But you were there during a very critical time, from 1981 to 1986, and we look forward to your comments.

So we are just going to ask you to proceed and tell us essentially from your perspective, what was the situation when Hubble was being developed. You know some of the questions we have in mind, and any information or insight you can share with the committee as you look back on those years. And I want to just state from my observation, Mr. Beggs, this is going to be a no-fault conversation. We are not putting the 1981 administration on the line and so on. We are really trying to get a picture of what happened so that we know how to either fix it or make sure those things do not happen again.

STATEMENT OF JAMES M. BEGGS

Mr. BEGGS. I understand, Madam Chair. I appreciate the opportunity. I come as a lamb to the slaughter because you have all my previous remarks on the record on the Hubble.

I am embarrassed, as is the agency, and distressed. No one is more disappointed in what has happened on the Hubble than I because no one was looking forward more eagerly to the results from this magnificent instrument than I was. And no one had greater anticipation of the benefits that will flow.

But as the previous witnesses have testified, the glass is more than one-half full, not more than one-half empty on the instrument. There is a lot of science that we can do, and the problems that we have encountered can be corrected. That is encouraging to me. And I hope it is encouraging to everyone in this room.

I sat at the back of the room and watched carefully as the reporters were making notes. I noted that when someone said the glass was more than one-half full there was no notes taken. But when someone said the glass was more than one-half empty there were a lot, which is fair. It is proper to study our mistakes and certainly this was a lulu.

I should be the last, I might add, to defend the contractor in this case.

But as was noted, the mirror has spherical aberration from center to rim of less than two microns, two-millionths of an inch, which is a small, but very vital error. As Dr. Fisk noted, that is several wavelengths. It means that it is out of focus.

Nevertheless, it is a mistake that in the modern day one can appreciate as being very small and well within the range of errors that we tend to make from time to time.

Having said that, I would make this comment with respect to the contractor. NASA had every right to expect that that contractor would grind that lens to the right figure. They came certified by

the Air Force. They came chosen because they had done this kind of work a number of times before.

When I got into the program in 1981 the lens had just about finished its grinding process; it had not yet been coated. But it had finished its grinding process. And I made a trip up to Danbury to assure myself—because the program had gone through a number of difficult pickups, if you will—to assure myself that the people at Perkin-Elmer were paying attention to the right things.

And one of the questions I asked is are we going to test this beautiful piece of equipment. And I was assured by all the people there, all of the experts there, that a proper test—and the proper test was described—that a proper test would be run.

In retrospect we were probably more interested at that time in the coating process than we were in the contour of the lens, being that the coating process was unique up until that point. It was a unique process that was going to take place. And, as has been described here by the previous witnesses, it was very vital to get the performance in the ultraviolet and the infrared, that that coating process be very carefully controlled. And with the virtue of 20/20 hindsight, we probably spent more time concentrating on how they were going to do the coating than we did on how they were going to measure the contour.

Be that as it may, we were assured by the people of the company, and we were assured as well by the very few people that we had in the plant at that time, that a proper test was to be run. And, indeed, a proper test was supposed to have been performed. It was so reported and is in the record. I will be very interested in seeing what Lew Allen comes up with as he proceeds through his investigation and where that went wrong because it is entirely within the art to measure the accuracy of a mirror to the performance requirements that we had specified.

Now, as the program progressed it ran into a number of difficulties, not the least of which was the fact that it overran significantly in cost. Overruns are something that we live with in this business. We tend to be quite optimistic when we go into programs on this. If you were not optimistic, you would not be in this business, I might add. But we tend to be optimistic going in and overruns are not unexpected, although the overruns that occurred on this, in that they were repeated a couple of times, were distressing.

Chairman Boland of the House Appropriations Committee held a hearing on the program when the latest of the overruns were disclosed by us to him and to the Congress and held a lengthy program. I recommend that report to you. I am sure that you have read it. It is comprehensive and inclusive and I think includes all the data that we had at that time.

Suffice it to say that we had started with a program which was in the order of $400 million and had run it up at that point to about $1.3 or $1.4 billion, if my memory serves, which was quite a large overrun.

It was a difficult time, and we were pushing to launch the telescope in 1985. Obviously, at that time with the problems we had encountered, we were not likely to make that date. And, indeed, as it turned out we did not make 1985. Then, of course, the *Challenger*

accident occurred and we were laid up for several more years. But we were aiming for a specific period of time.

I note by some of the press reports that the Air Force at that time had suggested to the program manager—incidentally, we changed program managers in that period of time because we felt that we had lost confidence in the Marshall Space Flight Center program manager who was in charge, although in fairness to him, he did not have the visibility into the program at Perkin-Elmer by reason of the fact that we had made an agreement with the Air Force that we put a limited number of people into that plant. You have been briefed on that outside of these hearings and I do not care to get into the reasons for that. But the plain facts were that we did not have the normal visibility that NASA has into major programs.

And the program manager at Marshall had, as I recall, only three or four people in the plant to oversee that program at that period of time. That is far too few for a normal program. But we were assured by a lot of different sources that adequate oversight was present there and that we would be allowed to get a visibility through the procedures that were in place.

In spite of that, at that time, I felt that we had to put increased oversight into the plant. So we established a team of 15 technical people from Marshall and from headquarters to locate up at Danbury to establish a management system that would allow us to get a better visibility into the program.

Now, unfortunately, by that time the error that we are talking about here today had long since been put into place. But we did put a management system in at that point which did, I believe, give us adequate visibility into the program to allow us to at least determine whether, administratively the Perkin-Elmer people were performing as they were required to perform in accordance with the contract.

At that time, or shortly thereafter, I left the program and had no additional access to it. I have not asked for—it is my view that administrators and chairmen of the board and other people should, after they leave their office, not interfere with the performance of their successors. And I have not, I have not inquired. And I have not, in any way, asked to get involved. So my only knowledge of the current situation is whatever is in the newspapers. And what I have read in the newspapers, as I have already said, is distressing and embarrassing. It fills me with a feeling of remorse.

However, I also feel that it is very important for the Congress to continue this program because I feel that the telescope is the most important scientific instrument that we have ever launched, maybe the most important scientific instrument that this Nation and the world has put into operation since the beginning of time. It allows us to consider some of the most profound questions that the human race can consider.

So I think it is exceedingly important that—given that we have made some mistakes, but given that we did have the foresight to design the instrument in such a way and—indeed, one of the crucial, technical issues during that period of time when we were confronted with these several problems were the latches that enable you to get at the instruments to replace them. The fact that we did

solve that problem, and I hope and trust and believe that they are adequate to the job, so that we will be able to replace the instrument as has been stated here before and get the full results of the telescope.

Madam Chair, I thank you again for the opportunity. I would be pleased to respond to any questions.

Senator MIKULSKI. Thank you, Mr. Beggs.

Just by way of background for people who are following this, really the Hubble space telescope was conceived in the 1970's. It was, indeed, an ambitious and grand design exactly for the reasons you said, a spectacular view of the universe, an important scientific tool and a commitment to the civilian space program.

By the time, however, that Hubble got to 1983 there was sufficient congressional dissatisfaction with that by Mr. Boland, the chairman of the House Appropriations Committee, that he ordered—they have an investigation team over there. It is called surveys and investigations. He ordered an investigation of Hubble because of what he referred to as technological problems, latches and the things you talked about and also in management, identifying issues particularly related to communications between headquarters and Marshall.

I am not going to go over all that ground with you, but in response to the Boland investigation you testified there, and you said this—this is in 1983—we succeeded very well with the mirror. It is exceedingly fine. It is even better than specifications. And I know you were very proud of the mirror because at that time it seemed to be the only thing that had been done right.

Could you tell us why you felt that the mirrors were better than NASA's own requirements and were there at that time any disputes within NASA and Perkin-Elmer about the mirror's quality?

Mr. BEGGS. No; it was so reported; And, of course as I said before, the thing that we were concentrating on at that time was the smoothness of the mirror, the coating, because the coating was exceedingly important. If there was any molecular contamination on the surface of the mirror it meant that we would not get the UV return, the ultraviolet return. And if there was dust present we would not get the return that we expected in the visible and infrared. And so the coating and our ability to put that coating on without any contamination was exceedingly important. It was the thing that we all were holding our breath, hoping nothing went wrong.

As I said, we had been assured by a number of people that the Perkin-Elmer people were exceedingly competent to grind the mirror to the figure that we required, to that one-fiftieth of a wavelength. They had done that before. And we had every right to expect they would and we ran a test to assure that. So, as I said——

Senator MIKULSKI. You ran a test to assure what?

Mr. BEGGS. That it was ground to the right figure.

Senator MIKULSKI. Well, first of all, you went up to Danbury——

Mr. BEGGS. I went up to Danbury. I did not test the mirror myself, Madam Chairman.

Senator MIKULSKI. You went up to make sure that it was running the way NASA had intended it to do.

Mr. BEGGS. Yes.

Senator MIKULSKI. You were assured at that time that they were doing proper tests. Did they describe for you the tests that they were undertaking?

Mr. BEGGS. Yes.

Senator MIKULSKI. Were you satisfied with the nature their tests?

Mr. BEGGS. Yes, I was. Well, I was not completely satisfied at the time, but I came back to NASA and asked the folks at headquarters whether they were satisfied with that tent. I am not an optics expert and do not claim to be. I asked them whether they were satisfied that that was an adequate test to test this mirror to the specification that we had required, that we had put into the contract. And they assured me it was. At that point, I was assured.

Senator MIKULSKI. So as NASA Administrator, you turned to the people who were to be knowledgeable about the array of tests that could be used?

Mr. BEGGS. That is correct.

Senator MIKULSKI. Did they assure you that the state-of-the-art tests were about to be done, or did they say things like well, Jim, given budget restraints and the record of the contractor and our experience on projects like this, we think that by a factor of something or other it is going to be all right.

Mr. BEGGS. To my certain knowledge, while we were concerned about the budget, and I will not deny that. Everybody who was there in the process felt the vent of some of my anger at some of those overruns, at no time did we cancel or obviate any test that we felt was necessary. We felt we were doing the necessary tests. We thought that we had an adequate check on the equipment that was going to be used to run those tests. And we thought that the people that we had employed to run that test were competent to run the test to specification.

Senator MIKULSKI. Now that takes me to the next part. Mr. Beggs, when they planned these tests and outlined them for you, did they say they were going to test whether the Hubble met specifications or were they going to test that the Hubble was going to work?

Mr. BEGGS. No; we tested to specification. We tested the mirrors individually. We talked about the question of assembling the telescope and testing it as a telescope. The feeling was that that would yield no information that we could not get by testing the primary and the secondary individually. And the belief was, and I think you will find, if you check the people who were involved at that time, that nearly everyone—I will put it this way, everyone that talked to me felt that the tests were adequate to assure ourselves that the telescope would work as advertised.

Senator MIKULSKI. Well, in the course of awarding the contract and then feeling that Perkin-Elmer had such experience, did NASA get a warranty from Perkin-Elmer that if it does not work, we get our money back? Do we have a warranty on Hubble?

Mr. BEGGS. I wish we did. Because now they are backed by General Motors and we might be able to collect.

Senator MIKULSKI. That and three hubcaps will get you.

Mr. BEGGS. The reason Perkin-Elmer sold out to General Motors is they got into financial distress and we would never have gotten the money even if we had such a warranty.

But in truth, the contract we had was a best-efforts contract, which is a term of art that I am very familiar with having been sued in Federal court for a best-efforts contract. It was a best-efforts contract, cost plus award fee. And it was a type of contract which NASA generally operates under with its contractors on an advanced technology device like this, which is to say that the Government, NASA, shares the responsibility for the development of that instrument with the contractor.

In short, NASA is fully as responsible as Perkin-Elmer for the mistake that was made. There is no fuzz on that as we say in the trade. We are fully responsible. We had the oversight responsibility.

The comment I made earlier was that we were not allowed to operate in the way that we normally operate. It is important that the chair recognize that because that is a key point.

We would normally have had many more people in the plant than we did in this case. Because of the restrictions, it was in short—and I am on record on this if you read that testimony before the Boland committee. I said at that time, maybe not in these words—I said it is an awkward way to operate without a prime contractor. We had to split the contracts. The systems engineering and integration [SE&I] contract was placed with Lockheed. The contract for the mirror and the pointing system and the latches was placed with Perkin-Elmer.

So it was a very awkward way of operating. And I did not do that. So I can neither claim credit nor point with any kind of suspicion at why it was done.

But the point is that contract was let in a very awkward way. It was a very awkward way to operate. And NASA was put in the position of not being able to oversee and have the visibility into that program that it normally does.

In spite of that in 1983 when the problems occurred that led to this report from the House, I felt that we had at least the responsibility for assuring ourselves, and therefore, we changed the program managers. We moved Dr. Spear out and put in Jim Odom who was a very experienced program manager, one of the best we have. I think Jim did a very adequate job in managing the program from that point on.

But again, in fairness to the previous program manager, he probably was doing all he could do because he did not have much visibility into what was going on up there.

Senator MIKULSKI. Well, Mr. Beggs, just to be sure I understand what you have said, the way then this began to operate, essentially Hubble had two prime contractors, NASA and Marshall and then Perkin-Elmer. And the prime contractor in Danbury, CT, because it does do DOD-type work, civilian personnel were not on the scene as would be normally if it were at, say, Martin-Marietta or McDonald—you know, the people who build things.

Mr. BEGGS. Just so the record is clear, Madam Chair, there were two contractors, two associate contractors in this. In effect, NASA was its own prime contractor. Lockheed was the contractor for the

systems engineering and integration into the so-called telescope mount. Perkin-Elmer was responsible for the so-called optical telescope assembly, which included the mirrors, the primary and secondary, the pointing system, the control system which kept the mirrors pointed very accurately, and the latches and the system that allowed us to change out the instruments as necessary.

So there were two contractors 3,000 miles apart. It was Lockheed in Sunnyvale, CA, and I might add Lockheed was very well qualified for that kind of business even though we had problems out there as well at a later period of time, and Perkin-Elmer in Danbury, CT, which was responsible for the OTA.

NASA was, in effect, acting as its own prime contractor out of Marshall. And the program manager out of Marshall was trying to manage this program, in effect, from Huntsville, AL, because there were only a very few people in the plant, as I say, as I recall, only three or four at that time.

Senator MIKULSKI. Senator Garn, why don't you proceed?

Senator GARN. Thank you, Madam Chair.

First of all, Senator Grassley apologizes for not being able to be here. He is tied up in another hearing and he asks unanimous consent that his questions for the first panel be submitted to them for their response in writing.

Senator MIKULSKI. Without objection.

Do you have any questions?

Senator GARN. Just a couple.

I was noticing in this book, Mr. Beggs, you are quoted in 1984, following on your comments about what a great instrument it was, and I agree with you, that the space telescope will be the eighth wonder of the world.

Mr. BEGGS. That's my words.

Senator GARN. And Eddie Boland's comment was it ought to be at that price. Eddie and I had many, many conversations about Hubble back in that period of time.

I realize, with all of your technical expertise in other areas, you are not an optical expert. And I certainly am not. But having listened to the previous testimony and from your knowledge from others, do you feel that the type of fix they are talking about is reasonable and possible within that timeframe?

Mr. BEGGS. As I understood him he said 1993. And certainly they ought to be able to do what is necessary to compensate by 1993.

As with some of the other things that were discussed here today that requires very careful planning for the mission, as you know, Senator. It will require an EVA which may be of fairly extended duration. So it will require a shuttle mission which is at a relatively high altitude and that may take a few more months. But certainly, within that general timeframe, I think it is possible. And I have great confidence that they can fix the instrument in the way they describe.

I might add that near as I can tell from what little I know about the measurements that have been taken what is wrong with the telescope is not yet fully understood. And, again, I think it is important that we wait for a few more months until we get more information as to what we did wrong. If indeed we find that it is worse or better than we think, it may be an easier fix later on.

It was always anticipated that it would take upward of 6 to 8 months to fully check out the instrument once we got it in orbit. And we are yet only a matter of 3 or 4 months into the mission. I think we need another several months to check it out fully.

While it is unfortunate and embarrassing what happened with the mirrors, it is encouraging and I think kind of a blessing that the other parts of the instrument which we worried about just as much as we did the optical part are working fine.

Senator GARN. I think interestingly enough there was a great deal more worry about pointing, guidance, all of that sort of thing and adjustments than there was about the mirrors. In all of the conversations I heard of people worrying about what would happen as a result of launch and all the potential problems, we are all pleased that none of those took place. At no time did I hear anyone who was worried about the mirrors. I guess everybody assumed they were all right.

As far as the EVA, if they are able to perfect the instrument, I would not be worried about that. As you well know, the rehearsal in the tanks down at Houston, whoever the two astronauts that were doing that, they would spend months, if not years, doing that operation over and over again in the tanks so that by the time they get out there it almost becomes, well literally, almost easier there because the water does not simulate the ease of movement that microgravity does. So I do not worry about that from that standpoint.

It is the technical side that I do not understand. Can they produce an instrument that will correct it? The rest of it, I think, is pretty straightforward.

Mr. BEGGS. If I can add a comment to that, Senator Garn, which I think is important, the greatest experience in maintaining an operating system in orbit is that which the Soviets have had with the Mir, which includes a lot of scientific instruments as well as the normal kind of space station activity that we intend to engage in once we get Space Station Freedom operating. The Soviets have had relatively little problem with their EVA activity. They conducted one yesterday which went off very successfully. And routinely they conduct those to inspect the status of the various instruments and the status of the capsules that they have in operation up there. They have had no problem.

I would emphasize, we tend to in this country anticipate more problems than we encounter. Just as you said, sometimes it is easier after you have gone through the training to do it in actuality then in the training cycle. In fact, the experience the Soviets have had is that they have relatively little difficulty in doing what they have done.

Senator GARN. That is a very good point you make. My earlier remarks to Dick Truly and others it only adds to what I was saying, if you are correct and that point has not been made. But NASA anticipates a lot more problems than ever occur, just the converse of what we are hearing. When something goes wrong all the piranha want to jump on it.

Mr. BEGGS. I was in NASA the first time during the Apollo program. At that time there was a credible scientific report that if we landed on the Moon, the astronauts were going to be drowned in a sea of dust because there was a mile deep pile of dust on the sur-

face of the Moon. We had run some tests which gave us confidence that was not happening.

But we could just as easily have blown that up into an enormous problem, which fortunately the folks who were running the program at that time did not feel was necessary. And it never amounted to anything. When we got there there was dust, but it was manageable and we lived with it and did very well.

Senator GARN. The point I wish to make is that, again, the system is working because my flight, and I suppose everybody would feel this way, was easier in the operation of it than doing the simulator everyday. What those simulator instructors could do in the anomalies and problems they created for the crew, particularly the pilot crew, over and over again. Those sessions in the long simulation were great ordeals compared to the flight. Just the hundreds of problems that could go wrong that the crew practiced over and over and over again.

So, again, I have to make the point that I think the record is much, much better than the critics would like tc have it portrayed.

Thank you, Madam Chair.

Senator MIKULSKI. Thank you.

Mr. Beggs, just a few more questions. There are those who say that the problem with quality control or quality management during the Hubble process was not due to limited access to Perkin-Elmer, but due to personnel cuts that occurred at Marshall and that the fiscal year 1981 budget, for example, cut 840 positions out of NASA.

My question to you is, What are your comments about that? Because the talk that comes to us is that NASA had faced very severe personnel cuts; that they were doing a shuttle scramble, meaning the shuttle was behind schedule, that NASA was running to catch up to get back on track for the shuttle program and essentially it deployed most of its people, including a lot of its best and brightest people in the shuttle program, thus perhaps cannibalizing some of the other projects that were underway, and that there was also no real fixed point for quality management in terms of some specific watchdog person assigned.

Do you want to comment on that?

Mr. BEGGS. I think it is a fair critique. NASA, at its peak, during the height of the Apollo days—and if you project the Apollo budget at the peak to let us say 1981, if my memory serves, it would have been about $20 billion in 1981. We had less than $10 billion in 1981, so we were spending a lot more money is what I am saying at the peak of Apollo in actual fact than we were spending in 1981. Nevertheless, the NASA employment at the peak of Apollo, if my memory serves, was about 33,000 or thereabouts and in 1981 it was about 22,000, so it had come down by one-third.

Moreover, one of the things that happened to us as we came down in employment is for a number of years we did not hire any fresh-outs. We did not hire the people who would, after 5 or 6 years, be the kind of individuals that you count on to tap for your key working management positions, the project management and key support people.

So there is no question but what NASA suffered by reason of the fact that it had come down in employment—there is nothing politi-

cal about this because it came down in the Nixon years and it came down in the Carter years and the Ford years. It continued down through 1981, which was the first year, then it turned up a tad.

When I got there I asked that at least we stop that nonsense because it is those key Government managers who are the ones you count on to highlight the kinds of problems that we ran into in this case. So I think that is a fair critique. Whether it had anything to do with the instant problem that we are discussing, I have no idea.

But it is fair to note that at the beginning of the telescope program in 1977 they restricted Marshall to, I think it was, 80 or 90 people on the program because of the manpower restrictions that they were under and because of the fact that they had made this agreement with the Department of Defense to restrict the total number of people who would be cleared into the facility up at Danbury.

So I think both points are pertinent. I think you can look to both points as having had some impact. How much impact, I have no idea. Again, we will have to wait for Lew Allen to tell us what the real problem was.

Senator MIKULSKI. Using again the example—the Hubble—as we look into the future, one of the things that I think is important to, essentially, a triad for NASA's future is a reliable transportation system. The other part I talk about is adequate funding of NASA's core, meaning it is the centers that really are the heart and soul of NASA—Marshall, Goddard, Houston, we could go around the country. That means adequate personnel, adequate equipment, deferred maintenance, which we are trying to do.

And I wonder, from your opinion now, just a shift from the Hubble, is it that often both that the politics of a lot of this drives us to look at things like projects that seem glitz and glamour and futuristic and enticing. But as we look at the projects often very exciting and futuristic, we do not look at the NASA core and, therefore, put bucks into a project rather than making sure that as we do we have funded the NASA core program. In this case, the Marshall Space Flight Center, which I visited and thought the people were extremely dedicated and tenacious and quite proud of the work that they do.

Do you see what I am saying? Very often Congress, a White House, an eager scientific community gets all mesmerized by a project because it sounds pretty glitzy. And over there is a skimpy number of people doing quality control or the person that sweats the details on dull things like checking the mathematical equations or, quite frankly, is fixing the plumbing or trying to get the asbestos out of buildings that are 50 years old.

Mr. BEGGS. All of those are key indicators of the health of the agency. If I were sitting where you are sitting, Madam Chair, I guess things I would look at is how many new fresh-outs, new Ph.D's and masters and baccalaureate-degreed individuals are we bringing into the agency every year. And I guess I would look at where they graduated in their class, as well. Although I do not believe that is an absolute indicator of how well they will do.

But how many of those are they bringing in, how well the facility, the resource is being managed and being replaced and replen-

ished as the facilities wear out. How well they can attract from time to time key people in from the outside world.

It used to be NASA could call on almost any technical individual in our society and he or she would come because it was such an exciting program that they wanted to be a part of it. That is no longer true, maybe not for obvious reasons, but it is no longer possible to call on anybody in this society. The Federal pay in the technical sense has not kept pace. And in addition to that, a lot of the things that have taken place in the last 10 years or 15 years make it a lot more difficult for people to make the transition.

But all those are indicators of how well the agency is doing and how well we are replenishing and keeping up with our technical position in the world.

If I may make one statement that I have to make for the record on where we stand in technology, this program is a key piece of science and technology for this country. It is a very important piece. Senator Garn mentioned in his remarks earlier, the fallouts that occur. But we must continuously replace the pool of science and technology that we have in this country if we expect to remain competitive in the world, and NASA is a key part of that. It is not the only part, but it is a key part of that. If we do not do that, we are going to continue to fall behind the world competitively.

Technology in the modern day is the source of national power. It is the well-spring of future wealth, and it is the thing that enriches our lives. If you have any doubts about that, simply look at Japan, a nation which has no natural resources and only the industry of a highly educated population that has made it one of the wealthiest nations in the world, simply by exploiting technology.

The requirement to do that, Madam Chair, is absolute on the Congress. It needs no justification, other than the fact that we must stay competitive in the modern world.

Senator MIKULSKI. I would agree with that, and yet Japan has a strategic plan. It does not pursue just any project. It usually has a scientific, and then ultimately a commercial use behind which it does its scientific research. Which then says, do you think we bite off more than we can chew? Do you think that we take on too many projects without the resources to do the job right? And that is my last question.

Mr. BEGGS. I think it is absolutely, perfectly appropriate and very responsible and important that the Congress continue to exercise its oversight on the agency to ensure that what it proposes to do are things that it can do, and are things that are important to the country. It is taxpayers money and the Congress is representatives of the people, and in exercising the kind of oversight that the people give them, should assure themselves that the programs that NASA pursues are appropriate to the purpose. If they are not, they should not vote the money.

And that applies to anything they bring, whether it be a telescope, manned and womanned space flight, a trip to Mars, a return to the Moon, a voyage to the planets, a look at the universe or anything else we do. It is perfectly appropriate that that be examined in the context of what they are capable of doing, what we can afford to do within in the context of the overall budget priorities in

this country, and what we need to do in order to maintain our competitive posture in the world.

Senator MIKULSKI. Thank you, Mr. Beggs. Senator Garn.

Senator GARN. I have no further questions.

ADDITIONAL COMMITTEE QUESTIONS

Senator MIKULSKI. Mr. Beggs, on behalf of the committee, we want to thank you for coming. I think you have taken us through a walk-through of what NASA looked like from 1981 to 1986. We do appreciate the fact that you came and the insights that you offered.

[The following questions were not asked at the hearing, but were submitted to the Department for response subsequent to the hearing:]

QUESTIONS SUBMITTED BY SENATOR FRANK R. LAUTENBERG

Hubble Telescope

Question 1: Did NASA consider using the Defense Department equipment to test the mirrors? If so, what were the specific reasons why the DOD testing equipment was not used?

Answer 1: Yes, NASA considered using Department of Defense (DOD) optical test facilities to validate the primary optics. However, there was no facility that could satisfactorily verify the adherence to specification of a 2.4 meter, diffraction limited mirror. Without such a facility, the ability to meet the performance requirements of the HST program could not be confirmed until after its initial focussing while on orbit.

Question 2: Does NASA ever use Defense Department facilities and expertise to test its equipment? Why or why not?

Answer 2: Yes. The Hubble Space Telescope program has used Defense Department facilities to support several of its technology developments. For example, HST Rate Gyro testing was done at Holliman Air Force Base using extremely quiet and precise DOD facilities. Also, NASA utilized the Air Force shipping container/C5-A aircraft to provide rapid and cost effective shipment of HST from Lockheed to the Kennedy Space Center. Where facilities are known to exist and are available, NASA and the DOD share when it is cost effective.

Question 3: Do the agencies share information about testing procedures? Are there areas where the agencies could cooperate more?

Answer 3: Yes. As in 2 above, where test procedures and other expertise are known to exist, and are applicable, an effort is made to share. For HST, a significant effort was made to maximize the use of existing national capabilities. All of the HST test philosophies and plans were published in open literature, presented at conferences and symposia, and readily available to the optics community for their review and comments. There may, of course, be areas for improved cooperation. However, the HST program took advantage of all expertise and technology, DOD as well as industry and academics, that could be made available.

Question 4: How much would it have cost NASA to test the mirrors together?

Answer 4: The ideal situation would have been to test the Optical Telescope Assembly (OTA) in its in space configuration in a zero gravity environment. Of course this is impossible on Earth, as the mirror flight mount causes deflections in 1 G resulting in astigmatism far in excess of the precision of the OTA system. However, testing could have been done using the manufacturing, metrology mount and a new secondary mirror fixture. This testing would have required a new facility, a large diameter optical flat ground to better precision than the

primary mirror, and a long test and analysis period. To verify that the assembled HST optical system met its specification, such a facility and additional HST schedule increases would have cost on the order of 100 million dollars. However, detailed cost estimates for such a test were never generated by Perkin-Elmer (now Hughes Danbury Optical Systems) nor NASA. From what is known today, the problem appears not to be in the two mirror system, but rather due to an, as yet, unknown manufacturing error in one of the mirrors.

Question 5: How was the decision made not to do that testing? Was it made at the Administrator level?

Answer 5: Large, complex space projects use a combination of mathematical analysis and actual testing to predict the ultimate performance. The strategy for the HST program was always to precisely measure each of the mirrors independently, and then use straightforward analyses to predict the performance of the assembled OTA system. This approach was endorsed by the optics community. Full aperture testing of the total OTA was never deemed meritorious by the contractor, by the optics community or by NASA. Our test concept was based on the premise that the primary and secondary mirrors could be individually fabricated and verified. The only remaining verification requirement was proper spacing between the two mirrors. This spacing was verified by a much simpler and less costly test than a full aperture end-to-end test.

Question 6: Is there any chance the telescope could be repaired in 1991?

Answer 6: Although quick solutions are currently being investigated, none have so far proved feasible. Therefore, there is little chance of repair in 1991.

Question 7: What is the likelihood of moving the repair date to 1992?

Answer 7: The time required to complete manufacture and test of the WF/PC II, then integrate it into a servicing mission precludes repair until 1993.

Question 8: In building and launching the Hubble Telescope, was any technology discovered that would help the United States maintain its competitive edge? Or is the mission of the Hubble Telescope to expand the knowledge of the international scientific community?

Answer 8: The HST is perhaps the most scientifically complicated and demanding mission flown by man to date. Many extremely difficult and diverse technical challenges were taken on and overcome during its development, with the exception of this serious spherical aberration problem. The HST today is a nearly flawless spacecraft. In visible light HST is somewhat better than the observatory on Mt. Palomar, and in ultraviolet light it has about 100 times better sensitivity and spectral resolution than the best instrument available to the world's

scientists. Although the primary mission of HST is space science, its development did produce many technological advancements; for example, large-scale thermally stable graphite epoxy structures, low noise rate gyros, nickel-hydrogen batteries for low earth orbit application, scientific detector technology which are being applied to new Earth-based instruments, high precision structural analysis techniques, large reaction wheels and their vibration isolators, and structural dynamics testing. These and other engineering/technology advancements contribute to maintaining the nation's international competitive position.

Question 9: Once the telescope is repaired and providing scientific data about the universe, will we share that data with the international community?

Answer 9: Yes. HST is truly an international observatory. The European Space Agency (ESA) is a partner in the HST program, having provided HST's solar arrays, one of the five science instruments (Faint Object Camera), and 10-15 manyears per year to support HST Science Institute operations.

The HST program has maintained a policy of open access for users of the telescope through a highly competitive selection process. International users have competed for, and won about 15 percent of the HST's total observing time. Most of the selected astronomical campaigns come from nations that are spacefaring

Question 10: (If the answer is yes) Did the international community help pay any of the $1.5 billion it cost to develop and put the hubble telescope in space?

(If the answer is no) If we plan to share, as opposed to competing with other nations, why don't they help foot the bill for this huge project?

Answer 10: The $1.5 billion was the HST development cost to NASA. The European Space Agency provided HST's solar arrays, one of the five science instruments (Faint Object Camera), and 10-15 manyears per year to support HST Science Institute operations. If the Europeans had not made these contributions, the costs of these would have had to be borne by NASA.

Shuttle

The Washington Post reported that the site of the leak in both Shuttles -- pipes connecting fuel tank to orbiter -- were part of a batch of eight tested at about the same time in 1984. According to the Post, all eight leaked during initial tetss at a California contractor facility, but conditions of the test were changed sosthat the hardware could pass. Of the eight, the two now installed in Columbia and Atlantis showed the greatest leadage durng initial tests.

Question 11: Are you aware of these reports? Were the conditions of the test changed so that the hardware could pass?

Answer 11: Yes, NASA is aware of these reports. No, the

tests were not changed to make the hardware pass. Test data on all umbilical connectors both tank and orbiter has been reviewed in detail as part of the on-going hydrogen leak investigation. These data show that the eight tank side disconnects in question did fail initial total system level leak tests when using a simulated orbiter side disconnect test fixture. Approved test procedures specified to retest with a flat plate in place of the orbiter side simulator to determine if the leak was in the flight hardware (tank disconnect) or the test fixture (orbiter side simulator). In each case the flight hardware passed this leak test, indicating that the test fixture was the leak source in the original test.

As part of the hydrogen leak investigation, a thorough review of the Acceptance Test Procedure is being made and modifications to improve the test are anticipated.

Question 12: To what extent were NASA representatives involved in those tests? Is there a need for a greater involvement by the agency in testing?

Answer 12: NASA representatives were not directly involved in these tests. These acceptance tests were conducted by the hardware supplier (Parker Hannifin) following detailed test procedures that were approved by the prime contractor (Rockwell International). Government oversite was provided by on-location DCAS inspectors to assure rigorous adherence to approved procedures. The intent of the tests and overall test protocol are established and approved by NASA; however, the detail test procedures are developed and approved by the prime contractor and subcontractors.

This process is considered a reliable one for an acceptance test of production hardware. There is considerable government oversight and involvement in major component development and qualification testing.

Space Station

There is growing concern about the increasing price tag on the Space Station. The most recent figure I have seen is $37 billion for construction costs through 1999. I understand the Japanese, Canadians and the Europeans Space Agency are expected to contribute $8 billion for the Space Station.

Question 13: Has any of that money been provided?

Answer 13: First, NASA's estimate for design and development of Space Station Freedom hardware is $18.5 billion in real year dollars (just under $12.3 billion in 1984 dollars). This estimate is well within the cap of $13 billion (1984 dollars) proposed by the Administration. The Polar Platform transfer not withstanding, this component of the program's costs estimate has remained stable for several years.

The $37 billion cost estimate is a recent projection of the total costs associated with development and operation of the

Space Station through the 1999 Assembly Complete milestone. It includes not only the development costs, but also the costs of operations, civil service, assembly flights, communications, construction of facilities, the Flight Telerobotic Servicer, and logistic/outfitting flights. This estimate is larger than previous response to earlier funding shortfalls. For example, the new estimate includes some operations and Shuttle costs in 1998 and 1999 that previously were beyond the assembly period.

Second, our agreements with the international partners provide for each partner to design and develop specific hardware elements, regardless of the ultimate cost. The partners did not financially support the development of hardware for which we are responsible and we do not financially support the development of hardware for which they are responsible. The current estimated value of the three partners' hardware contribution is approximately $8 billion in real year dollars.

Questions 14 & 15: If the projected cost of the Space Station increases, are there plans to seek additional contributions from our international partners?

Answers 14 & 15: The agreements specify that the international partners will provide specific pieces of hardware, not a fixed value of hardware or services. This approach is the traditional way of constructing international cooperative programs.

The same agreements also state that all partners will share in paying for common operating costs of the Space Station. These costs will be shared by all partners in proportion to the agreed to percentages of Space Station utilization.

We have no plans to seek additional contributions from the partners.

QUESTIONS SUBMITTED BY SENATOR CHARLES E. GRASSLEY

Question 1: Is NASA's research capability in non-destructive evaluation (NDE) being fully applied to the materials problems limiting the Space Shuttle's air worthiness.

Answer 1: The Space Shuttle's flight profiles are constrained by the physical limits of structural loading, as is the case with any flying machine, but the spacecraft's air worthiness is in no way limited by materials problems.

To assess the integrity of Space Shuttle structures and components, several innovative and NASA-unique non-destructive evaluation (NDE) techniques are presently used by the Space Shuttle program. NASA's Langley Research Center, Virginia; Marshall Space Flight Center, Alabama; and Johnson Space Center, Texas, are at the leading edge of research in this field and new techniques are rapidly assimilated into the operational program. Johnson Space Center issued a request for proposal (RFP) in 1988 for delivery of an operational NDE system. Zoinic, Inc., of Cincinnati, Ohio was awarded a contract for a system which

completed acceptance testing in the fall of 1989. The process imparts low amplitude, random vibration across structural components. A system of computers, accelerometers, and specialized programs analyze the signature of these vibration patterns to detect changes in structural characteristics. The OV-104 body flap has just completed evaluation through this process. This method of NDE inspection is particularly useful because visual inspection of Shuttle orbiter components is complicated by the thermal protection tiles which cover the vehicle and obscure the surface.

Another innovative NDE procedure in use is the Langley-developed ultrasonic technique of examining bolts and fasteners for preloads. This has been demonstrated to be a reliable means of disclosing hidden defects and imperfections which are otherwise undetectable. NDE techniques are also used to inspect liner bondlines and other features of the Redesigned Solid Rocket Motors.

NASA is cognizant of the enormous benefits which the Shuttle program can derive from NDE techniques and is committed to further developing and improving these methods and assimilating them into the program. Toward this end, NASA has begun to organize an agency-wide NDE Oversight Steering Committee. The Steering Committee will be charged with the responsibility to provide broad guidance and coordinated planning for identifying and meeting agency needs. Both short-term developmental needs of specific programs, and long-term NDE requirements of the agency will be within the scope of the Steering Committee. A NASA Management Instruction is in preparation which would officially sanction the Steering Committee and initiate its function in early 1991.

Question 2: Is NASA fully utilizing the rapidly developing National Science Foundation Center for Non-Destructive evaluation to address the problems of materials reliability?

Answer 2: Numerous interactions exist between NASA and the National Science Foundation Center for Nondestructive Evaluation at Iowa State University. NASA provides direct financial support to the Center for research in the area of magnetic measurements for NDE. NASA researchers contributed 16 technical papers to the Center's 1990 Conference on Quantitative NDE. Senior managers from NASA and the NSF Center communicate with one another, both formally and informally, and discussions concerning further technology transfer activities are being undertaken.

Question 3: What Interagency Agreements exist between NASA and NSF in the area of advanced materials testing reliability?

Answer 3: No formal agreements exist between NASA and the National Science Foundation (NSF) in the area of materials testing and reliability. However, numerous points of contact and mutual interactions exist at many levels between NASA-funded activities and NSF-funded activities in materials science and technology.

CONCLUSION OF HEARING

Senator MIKULSKI. This concludes today's hearing on the Hubble space telescope. The subcommittee will stand in recess until the call of the Chair.

[Whereupon, at 3:58 p.m., Wednesday, July 18, the hearing was concluded, and the subcommittee was recessed, to reconvene subject to the call of the Chair.]

36-778 (64)